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THERMAL DESIGN OF BOILER UNIT (STANDARD METHOD).(U)
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# FOREIGN TECHNOLOGY DIVISION

THERMAL DESIGN OF BOILER UNITS
(Standard Method)

FTD- ID(RS)T-0411-80

# UNEDITED MACHINE TRANSLATION

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141 gm

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## U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

| Block | Italic | Transliteration | Block | Italic | Transliteration |
|---|---|---|---|---|---|
| А а | *А а* | A, a | Р р | *Р р* | R, r |
| Б б | *Б б* | B, b | С с | *С с* | S, s |
| В в | *В в* | V, v | Т т | *Т т* | T, t |
| Г г | *Г г* | G, g | У у | *У у* | U, u |
| Д д | *Д д* | D, d | Ф ф | *Ф ф* | F, f |
| Е е | *Е е* | Ye, ye; E, e* | Х х | *Х х* | Kh, kh |
| Ж ж | *Ж ж* | Zh, zh | Ц ц | *Ц ц* | Ts, ts |
| З з | *З з* | Z, z | Ч ч | *Ч ч* | Ch, ch |
| И и | *И и* | I, i | Ш ш | *Ш ш* | Sh, sh |
| Й й | *Й й* | Y, y | Щ щ | *Щ щ* | Shch, shch |
| К к | *К к* | K, k | Ъ ъ | *Ъ ъ* | " |
| Л л | *Л л* | L, l | Ы ы | *Ы ы* | Y, y |
| М м | *М м* | M, m | Ь ь | *Ь ь* | ' |
| Н н | *Н н* | N, n | Э э | *Э э* | E, e |
| О о | *О о* | O, o | Ю ю | *Ю ю* | Yu, yu |
| П п | *П п* | P, p | Я я | *Я я* | Ya, ya |

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

## RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

| Russian | English | Russian | English | Russian | English |
|---|---|---|---|---|---|
| sin | sin | sh | sinh | arc sh | $\sinh^{-1}$ |
| cos | cos | ch | cosh | arc ch | $\cosh^{-1}$ |
| tg | tan | th | tanh | arc th | $\tanh^{-1}$ |
| ctg | cot | cth | coth | arc cth | $\coth^{-1}$ |
| sec | sec | sch | sech | arc sch | $\text{sech}^{-1}$ |
| cosec | csc | csch | csch | arc csch | $\text{csch}^{-1}$ |

| Russian | English |
|---|---|
| rot | curl |
| lg | log |

Page 1.

THERMAL DESIGN OF BOILER UNITS.

(Standard method).

With an appendix of calculation nomograms

Page 2.

The standard method of the thermal design of boiler aggregates/units is comprised together by All-Union to heat engineering and central boiler and turbine ones by institutes and is predicated by the technical review boards of MTM, MES and MSES as obligatory for enterprises in these ministries. The presentation of calculation procedure, in the book are placed the calculated standards and the nomograms, which permit for experimental calculators to perform calculation, without turning to the basic text.

In appendices to the calculation method are given the tables of enthalpy and of specific volumes of water and water vapor, calculation of steam coolers, determination of the calculated temperature of the metal of the wall of ducts, short indications according to the design of combustion systems and heating surfaces and exemplary/approximate thermal design of boiler aggregate/unit.

The book is intended for the designers and builders of boiler aggregates/units, and also for the engineers of power stations and students of the highest technical educational institutions.

Page 3

PREFACE

The method of the thermal design of boiler aggregates/units is comprised together VTI and TsKTI and is predicated by the technical review boards of MTM, MES and MSES for the necessary use/application during the design of steam boilers in enterprises in these ministries is mutual the norms of the thermal design of boiler aggregate/unit, released by TsKTI (Mashgiz, 1945), and the norms, worked out by VTI (Gosenergoizdat, 1952).

During the development of final recommendations are taken into consideration the observations of special boards of MTM and MES, which critically studied propositions of VTI and TsKTI, and also the observations of different organizations and enterprises, done about the project of the method of calculation which in a somewhat reduced form was published in the journal "Thermal-power engineering" in 1954-1955.

The worked out materials consist of text with the detailed presentation of the procedure of calculation, calculated standards and nomograms. In the calculated standards (RN) it is repeated

briefly, without the explanations, calculation procedure is given the necessary reference material, which allows after detailed familiarization with the calculation method to perform calculation, without turning to the basic text.

In appendices to the calculation method they are given:

I. Conditional designations.

II. Table of enthalpy and specific volumes of water and water vapor.

III. Calculation of steam coolers.

IV. Determination of the calculated temperature of the metal of the wall of ducts.

V. Short indications in accordance with the design of combustion systems and heating surfaces.

VI. Exemplary/approximate thermal design of boiler aggregate/unit.

The method of the thermal design of boiler aggregates/units is

comprised to a considerable extent on basis of Soviet investigations, primarily by VTI and TsKTI, and it totals the results of the basic scientific research work of institutes in the field of study of the working processes of steam boilers and improvement of the calculation methods.

Material chapter 2 "Fuel/propellant" is based on the results of the long-term investigations of the good-quality characteristics of Soviet fuels/propellants, carried out in basic VTI under the direction of A. I. Korelin [deceased].

The results of the prolonged investigations of the physical characteristics of gases, water and water vapor, carried out in VTI under the management/manual of D. L. Timrot and N. B. Vargaftik, are placed into the basis chapter 3 the "Physical characteristics, used in the thermal design of boiler aggregates/units" and appendices of the II "Table of enthalpy and specific volumes of water and water vapor".

In chapter 4 "Volumes and enthalpy of air and combustion products", and also in chapter 5 the "Heat balance of boiler aggregate/unit" are used the materials of the old norms of the thermal design of MTM (worked out by TsKTI) and MES (worked out by VTI).

Material chapter 6 the "Calculation of heat exchange in the heating" is constructed on the method of calculation of heat exchange in the furnace chamber/camera, worked out in TsKTI under A. M. Gurvich's management/manual with P. N. Kendys's collaboration. In connection with the preparation of standard method calculation formulas and coefficients are additionally refined with the use of new experimental data of VTI, TsKTI and CSRI im. Krylov on the heat exchange in the heatings, and also taking into account the results of the research works in this region, carried out by N. V. Kuz'min, M. M. Rubin, Ya. P. Storozhuk and V. D. Terent'yev.

Were used also the results of theoretical developments of VTI (V. N. Timofeyev) regarding the angular coefficients and emissivity factor of furnace radiation/emission.

Chapter 7 totals the results of the large complex of the Soviet investigations of the physical processes, which occur in the convective heating surfaces. The methodology of the calculation of the convective heat exchange in the transversely streamlined bundles of ducts and heat exchange in the finned economizers and the air preheaters is based on carried out under N. V. Kuznetsov's management/manual in VTI investigations, in which participated I. B.

Varavitsikiy, E. S. Karasin, V. A. Lokshin, A. Z. Shcherbakov et al. The general/common/total procedure of calculation of heat exchange in the bundles of finned tubes is based on the work of VTI, carried out by E. S. Karasina. For the derivation of calculation formulas are used also the results of those carried out in TsKTI by V. M. Antufshchev and by G. S. Beletskiy the investigations of heat exchange in the banks of smooth, finned and fin tubes.

The calculation of heat exchange during the flow in the ducts and the longitudinal flow around the banks of tubes, in slot channels and the channels of the packing of regenerative air preheaters is based on the works, carried out in TsKTI under the direction of L. I. Il'in [deceased]. In this section of standard method are used the data of D. M. Ioffe (MVTU) about the heat exchange in the regenerative air preheaters.

Page 4.

The calculation of the radiation/emission of combustion products is constructed on the results of the new compound processing of experimental data on the radiation/emission of triatomic gases and laboratory findings of the emitting properties of ash dust. These works are carried out in TsKTI by A. G. Blokh, V. V. Mitor and A. I. Nosovitskiy under A. M. Gurvich's management/manual.

The procedure of calculation of the contamination factors of tube banks is based on the laboratory investigations, carried out in VTI by N. V. Kuznetsov and A. Z. Shcherbakov, and uses results, previously obtained by M. D. Parasenko during processing of given commercial tests of steam boilers. Corrections to the laboratory values of contamination factor are established/installed during studying of standard calculation by E. S. Karasina (VTI), S. I. Mochan and O. G. Revzina (TsKTI).

The procedure of calculation of the temperature heads is worked out in TsKTI by S. I. Mochan.

For the determination of the excess air ratios, furnace losses, coefficients in the formulas of the calculation of heat exchange in the heating and the convective heating surfaces are used the results of commercial tests of the boiler aggregates/units, carried out in basic TsKTI and VTI (A. P. Baranov, I. K. Barshteyn, M. I. Bermann [deceased], S. G. Beskin, G. A. Burgvits, A. M. Gurvich, A. I. Dvoretskiy, V. N. Deshkin, I. Ye. Dubovskiy, N. I. Zhirnov, P. N. Kendys', M. L. Kisel'got, A. N. Lebedev, A. U. Moroz, Ye. V. Nechayev, M. M. Rubin, P. G. Sal'kov, S. V. Tatishchev G. A. Sheynin, M. M. Shil'dkret [deceased] et al.), and also at KBK LMZ (Ye. M.

Kazarnovskiy) and by other organizations.

Besides these works, during the composition of the standard calculation method were used the materials of old norms of MTM and MES.

In the preparation of materials for the individual chapters of the standard calculation method took part K. A. Alekseyev (Section "e" chapter 7), I. K. Barshteyn (chapter 5, §E chapter 4 and appendix V), A. G. Bloch (chapter 6, Section "c" chapter 7), I. B. Varavitskiy (§A chapter 4, chapter 5, appendix I), N. B. Vargaftik (chapter 3), A. M. Gurvich (chapter 5 and 6, Section "c" chapter 7 and of appendices V), A. I. Dvoretskiy (data on the petroleum residue for chapter 2 and 3), A. A. Zakharov (appendix IV), L. N. Il'in [deceased] (Section "b" chapter 7), E. S. Karasina (chapter 6, Section "b", "d" and "e" chapter 7 and of chapter 8), P. N. Kendys' (chapter 5 and 6 and appendix V), A. I. Korelin [deceased] (chapter 2), N. V. Kuznetsov (Section "b", "d" and "e" chapter 7 and of appendices V), A. N. Lebedev (chapter 5 and application/appendix V), S. I. Mochan (§B chapter 4, Section "e" and §C chapter 7, chapter 8, appendix III and IV), S. P. Nevel'son (chapter 5, Section "e" chapter 7 and of appendices V), M. D. Panasenko (chapter 2, Section "e" chapter 7), O. G. Revzin (§E chapter 4, Section "e" chapter 7 and of appendix III, IV and VI), M. M. Rubin (chapter 5), A. B. Sternin

(chapter 6), S. A. Tager (RN 5-G3 and 5-C4), S. V. Tatishchev (chapter 5 and appendix V), G. A. Sheynin (chapter 5 and appendix V), A. Z. Shcherbakov (Section "d" chapter 7), V. A. Shcherbakov (appendix V) et al.

In discussion and agreement of basic fundamental questions of the standard calculation method took active part I. K. Barshteyn, P. N. Kendys' and M. D. Panasenko.

Leadership of entire work exercised A. M. Gurvich and N. V. Kuznetsov.

Basic part of the text (chapter 1, 3, 4, 5, 7 and 8 and appendix III, IV and VI) was compiled by E. S. Karasina and S. I. Mochan; chapter 2 - by A. I. Korelin [deceased] and T. A. Zikeyev, chapter 6 - by A. M. Gurvichem, A. G. Bloch and S. I. Mochan, appendix V - by I. K. Barshteyn, E. S. Karasina, M. L. Kisel'gof, S. I. Mochan and G. A. Sheynin.

In the composition of calculated standards and nomograms, besides the authors of text, they participated C. G. Revzin and Ye. Ya. Titov.

Pages 5-6.

No typing.

Page 7. Chapter One.

GENERAL POSITIONS.

1-01. "Thermal design of boiler aggregates/units (standard method)" contain operating instructions, reference materials, calculation formulas and nomograms, necessary for executing verifying and structural/design (designed) thermal designs of stationary boiler aggregates/units.

The methodology of verifying and construction calculations is in essence of general/common/total. Difference consists for the purpose of calculation and unknown values.

1-02. In verifying thermal design by construction/design accepted and sizes/dimensions of boiler aggregate/unit for design load of its and prescribed/assigned form of fuel/propellant determine temperatures of water, vapor, air and gases on boundaries/interfaces between separate heating surfaces, efficiency, fuel consumption, flow rate and air speeds and flue gases.

Verifying calculation is produced for evaluating of efficiency/cost-effectiveness and reliability of aggregate/unit,

determination of the necessary reconstructive measures, selection of auxiliary equipment and obtaining initial data for conducting the calculations of the circulation of water, temperatures of metal, etc.

1-03. During structural/design (designed) calculation are determined sizes/dimensions of heating and surfaces of heating separate elements/cells of aggregate/unit, necessary for obtaining of rated steam capacity, indices of economy and prescribed/assigned parameters of accepted steam (pressure and temperature) at given temperature of feed water and propellant properties.

The rated steam capacity is called the highest efficiency which the aggregate/unit must provide with the observance of the prescribed/assigned parameters of steam in the prolonged operation.

Into the task of calculation enters also the determination of necessary for the selection of auxiliary equipment of the consumptions of fuel, air and flue gases.

During the calculation must be taken into consideration the guarantee of reliability of the operation of aggregate/unit (warning/prevention of slagging or ash fouling of surfaces, warning/prevention of intense cinder erosion of ducts, superheating and corrosion of metal, etc.). If necessary on the basis of thermal

calculation additionally are produced the calculations of circulation, temperature of metal, speed of cinder erosion.

1-04. Calculated assignment for verifying thermal design of boiler aggregate/unit must contain the following information and initial data:

a) drawings of boiler aggregate/unit and information about construction/design and sizes/dimensions of combustion system, surfaces of heating and flues, sufficient for determining of all necessary structural/design characteristics;

b) propellant property in accordance with requirements, led in chapter 2;

c) coefficient of evaporation of aggregate/unit, pressure and temperature of superheated steam in main output catch (and limits of standard deviations with respect to conditions of work of turbines and other users of steam), temperature of feed water, pressure in boiler barrel;

d) at the presence of intermediate steam superheater - flow rate and parameters of the secondary steam at the entrance and the output/yield;

e) the flow rate of the saturated steam (during the selection of steam from the boiler barrel);

f) the value of the continuous blasting;

g) data of the calculation of the system of the pulverized coal preparation: the total quantity of air cloud, quantity of primary air and flue gas, selected/taken to drying, quantity of sucked air in the system of pulverized coal preparation.

1-05. During structural/design (designed) thermal design assignment must contain following initial data:

a) information about type of combustion system and planned layout of aggregate/unit;

paragraphs "b" - "g" - the same as in assignment for verifying thermal design.

The temperatures of stack gases and hot air are indicated in the assignment or they are selected in accordance with the recommendations of appendix by the V and specific conditions of

design.

The temperatures of gases at the end of the heating and in the flues, the gas velocity, water and steam and enthalpy of water and steam at the separate intermediate points of the steam-water channel can be selected in accordance with the recommendations of appendix the V and taking into account the specific conditions design.

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Chapter Two.

FUEL

2-A. Solid and liquid propellant.

A) Heat of combustion.

2-01. Heat of combustion (calorific value) of solid and liquid propellant is accepted according to data of calorimetric determinations. Use for calculating the values of heat of combustion, calculated in composition of fuel/propellant with the help of the empirical formulas of the type of Mendeleyev's formula, is not recommended.

2-02. Heat of combustion highest $Q_в$ is determined by value of heat of combustion in calorimeter $Q_б$, corrected taking into account acid-formation with combustion:

$$Q_в = Q_б - 22{,}5S_б - 0{,}0015Q_б \quad \text{kcal/kg} \qquad (2\text{-}01)$$

where 22.5 $S_6$ - heat of oxidation of products of burned down in bomb sulfur $S_6$ [o/o] from $SO_2$ to $SO_3$ and dissolution of latter in water; 0.0015 $Q_6$ - heat of formation of nitric acid in bomb.

2-03. Heat of combustion lowest $Q_н$ is determined by subtraction from heat of combustion of highest $Q_в$ heat of vaporization, conditionally equal to 600 kcal/kg of water adopted:

$$Q_н = Q_в - 6(W + 9H) \quad \text{kcal/kg.} \qquad (2\text{-}02)$$

2-04. During combustion in calorimeter of schists and other fuels/propellants, which contain carbonates, latter in majority of cases are decomposed/expanded virtually completely. Therefore heat of combustion during the calorimetric measurement is determined taking into account the negative thermal effect of the decomposition/expansion of carbonates [-9.7 $(CO_2)$ ] kcal/kg.

B. Different masses of fuel/propellant and recalculation of characteristics from one mass to another.

2-05. Propellant properties can be related:

to working mass of fuel/propellant (designated by index p), i.e., to fuel/propellant in that form, in which it enters for

consumption (into boiler room, dust-plant, etc.);

to analytical mass (index a), i.e., to fuel/propellant in that form, in which it in laboratory it enters for separate analytical determinations, crushed and dried slightly;

to dry mass (index c), i.e., to fuel/propellant, which does not contain moisture (W=0);

to the combustible mass (index d), i.e., to the sum of the elements/cells, which compose the organic mass of fuel/propellant, and pyritic sulfur.

For all fuels/propellants, except the containing a large quantity carbonates, for the combustible mass conditionally they accept (100-W-A), where 100 - working or analytical mass of fuel/propellant, o/o.

For the fuels/propellants with the high content of the carbonates (it is more than 5o/c) for the combustible mass it is accepted

$$[100 - W - A_{испр} - (CO_2)_к],$$

where $(CO_2)_к$ - content of carbonic acid of carbonates, o/o; $A_{испр}$ - ash content without taking into account sulfates, which were being formed

during the decomposition/expansion of carbonates, and with the correction for the combustion of sulfur of pyrite, c/o:

$$A^p_{ucnp} = A^p - [2,5\,(S_a - S_{cm})^c + 0,375\,S^c_\kappa]\left(1 - \frac{W^p}{100}\right)\%. \qquad (2\text{-}03)$$

where $S_a$ - content of sulfur in the laboratory ash (in the percentages to the mass of fuel/propellant); $S_{cm}$ - content of sulfate sulfur in the fuel/propellant; $S_\kappa$ - content of pyritic sulfur in the fuel/propellant.

In the absence of the laboratory data about the content of sulfates value $[2,5\,(S_a - S_{cm})^c + 0,375\,S^c_\kappa]$ they take as equal for Estonian and Gdovsk schists -2.0, Kashipsk -3.8, Savel'yev -3.1 and Ozinsk -2.4o/o.

This conditional calculation is explained by the fact that during the fuel combustion with the high content of carbonates the latter (in essence of $CaCO_2$, and also $MgCO_3$ and $FeCO_3$) are decomposed/expanded into oxide of metal and $CO_2$. Separated carbonic acid is removed together with the combustion products of the organic mass of fuel/propellant, whereas oxide of metal remains in the ash and due to the partial connection of sulfur oxides forms sulfates.

Of the determinations of each mass of fuel/propellant follow the obvious relationships/ratios:

$$C^p + H^p + N^p + O^p + S^p_\kappa + S^p_{op} + A^p + W^p = 100\%;$$
$$C^a + H^a + N^a + O^a + S^a_\kappa + S^a_{op} + A^a + W^a = 100\%;$$
$$C^c + H^c + N^c + O^c + S^c_\kappa + S^c_{op} + A^c = 100\%;$$
$$C^r + H^r + N^r + O^r + S^r_\kappa + S^r_{op} = 100\%.$$

The recalculation of the propellant composition, output/yield of volatile components and heat of combustions (in the bomb and the highest) is produced with the help of the factors, given in Table 2-1.

2-06. Recalculation of elementary composition to heat of combustions (in bomb and highest) of working mass with humidity $W_1^p$ to mass with humidity $W_2^p$ is produced by method of multiplication on $\frac{100-W_2^p}{100-W_1^p}$, and with ash content $A_1^p$ to ash content $A_2^p$ (when $W^p = \mathrm{const}$) - by multiplication on $\frac{100-A_2^p}{100-A_1^p}$.

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For the schists the recalculation of data of composition (C, H, N, O, $S_k$, $S_{op}$) and heat of combustion (in the bomb and the highest) from the working mass to the fuel is produced with the help of the factor

$$\frac{100}{100-W^p-A^p_{ucnp}-(CO_2)^p_k}.$$

The recalculation of data of composition and heat of combustion (in the bomb and the highest) from the working mass, which is

characterized by ash content $A_1^p$ and content of carbonic acid of carbonates $(CO_2)_{K1}^p$ to the working mass with $A_2^p$ and $(CO_2)_{K2}^p$ is produced with the help of the factor

$$\frac{100 - A^p_{ucnp2} - (CO_2)^p_{K2}}{100 - A^p_{ucnp1} - (CO_2)^p_{K1}}.$$

2-07. Calculation of lowest heat of combustion of fuel/propellant $Q_н$ is produced according to formulas:

$$Q_н^p = Q_в^p - 6(W^p + 9H^p) \text{ ккал/кг } (1) \quad (2\text{-}04)$$

$$Q_н^c = Q_в^c - 54\,H^c \text{ ккал/кг } (1) \quad (2\text{-}05)$$

$$Q_н^г = Q_в^г - 54\,H^г \text{ ккал/кг } (1) \quad (2\text{-}06)$$

$$Q_н^p = Q_н^г \frac{100 - W^p - A^p}{100} - 6W^p \text{ ккал/кг } (1). \quad (2\text{-}07)$$

Key: (1). kcal/kg.

The recalculation of the lowest heat of combustion of the working mass of fuel/propellant with humidity $W_1^p$ to the mass with humidity $W_2^p$ is produced according to the formula

$$Q_{н2}^p = (Q_{н1}^p + 6W_1^p)\frac{100 - W_2^p}{100 - W_1^p} - 6W_2^p \text{ kcal/kg.} \quad (2\text{-}08)$$

By a change in the ash content of working mass recalculation $Q_н^p$ is produced according to p. 2-06.

C) The classification of carbon/coals.

2-08. Coal it is accepted to divide into three basic types:

brown, stoneware and arthracite. There are no precise boundaries/interfaces between them; division itself into three types is conditional, and between them there are transient carbon/coals.

2-09. Brown coal (brand B) include noncaking coal with high output/yield of volatile components (>40%) and low in comparison with coals heat of combustion (Q in majority of cases lower than 7000 and not above 7300-7400 kcal/kg). They are characterized by always high hygroscopic and - in the majority of the cases - by high overall humidity, lowered/reduced by the carbon content and increased of oxygen. They easily lose in air mechanical strength, frequently becoming in this case the solid trifle, and they possess the increased tendency toward the spontaneous combustion.

According to the predicated classification the brown coal divide into three groups in the content in them of the general/common/total working moisture W:

$B_1$ - with the moisture content is more than 40o/c; $B_2$ - with the moisture content 30-40c/c; $B_3$ - with the moisture content to 30o/c.

Table 2-1. Factors for the recalculation of the propellant composition, output/yield of volatile components and heat of combustion (in the bomb and the highest) from one mass of fuel/propellant to another.

| (1) Заданная масса топлива | (2) Искомая масса топлива | | | |
|---|---|---|---|---|
| | (3) рабочая | (4) аналитическая | (5) сухая | (6) горючая |
| 3 Рабочая | 1 | $\frac{100-W^a}{100-W^p}$ | $\frac{100}{100-W^p}$ | $\frac{100}{100-W^p-A^p}$ |
| 4 Аналитическая | $\frac{100-W^p}{100-W^a}$ | 1 | $\frac{100}{100-W^a}$ | $\frac{100}{100-W^a-A^a}$ |
| 5 Сухая | $\frac{100-W^p}{100}$ | $\frac{100-W^a}{100}$ | 1 | $\frac{100}{100-A^c}$ |
| (6) Горючая | $\frac{100-W^p-A^p}{100}$ | $\frac{100-W^a-A^a}{100}$ | $\frac{100-A^c}{100}$ | 1 |

Key: (1). Prescribed/assigned mass of fuel/propellant. (2). Unknown mass of fuel/propellant. (3). worker. (4). analytical. (5). dry. (6). fuel.

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2-10. Stoneware ones include carbon/coals with output/yield of volatile components $V^г$-9-50% and it is above. Their bulk to the different degree is sintered, and only the part of carbon/coals with the output/yield is the volatile more than 42-45o/o (long-flame) and less than 15o/o (lean) are not sintered.

Coals are divided into the series/row of the brands/marks, which are distinguished by the output/yield of volatile components and by the degree of the sinterability, characterized by strength and appearance of nonvolatile remainder/residue. The acted up to now marking of carbon/coals of Donbass is given in Table 2-2.

Coals of other deposits were marked in essence in connection with marking of carbon/coals of the Donbas. Furthermore, were applied the following brands/marks: SS- mildly sintered carbon/coal; PPM - the intermediate product (semi-finished product) of the wet concentration; PPS - the same of dry concentration.

At the present time for coals of the USSR is predicated the system of the marking according to which carbon/coals are divided into the brands/marks on the output/yield of volatile components and degree of sintering, characterized by the thickness of plastic layer "y".

The lower limit of value y, expressed in millimeters, is entered as the index to the designation of the brand/mark of carbon/coal. For example: $G_{10}$ - gas in minimum thickness of plastic layer 10 mm.

2-11. To anthracite (brand A) carry carbcn/coals with output/yield of volatile ccmponents $V^{r}$ = 2-9o/c and heat of ccmbustion $Q^{r}_{h}$ < 8350 kcal/kg.

2-12. Transient between coals and anthracite are carbonaceous coal (brand PA, $V^{r}$ = 5-10c/o), which differ from anthracite of higher heat of combustion ($Q^{r}_{h}$ >8350 kcal/kg).

2-13. In view of the fact that for new brands/marks no yet sufficient reliable average/mean quality coefficients, design characteristics of fuel/propellant are given in norms in connection with old marking. Exception are characteristics for the newly established/installed brand/mark "carbonaceous coal".

2-14. Out of given above diagram of classification of coal remain geologically cxidized stoneware and brown coal. An example of the first are carbon/coals, obtained in the sections/cuts of the Kuznetsk Basin, the second - sooty carbon/coals of Moscow basin. Cxidized are also carbcn/coals of virtually all new developed/processed deposits of Central Asia, also, in particular Angren deposits, Kyzyl-Kiya, Sulyukta, Shurab (marked as brown).

Table 2-2. Marking cartcn/coals of Donets basin.

| (1) Наименование марок | (2) Обозначение | (3) Выход летучих веществ на горючую массу, % | (4) Характеристика нелетучего остатка |
|---|---|---|---|
| (5) Длиннопламенный . . . . . . | Д | (5a) Более 42 | (6) Порошкообразный или слипшийся |
| (7) Газовый . . . . . . . . . . . | Г | 35÷44 | (8) Спекшийся, сплавленный, иногда вспученный (рыхлый) |
| (9) Паровичный жирный . . . . . | ПЖ | 26÷35 | (10) Спекшийся, сплавленный, плотный или умеренно плотный |
| (11) Коксовый . . . . . . . . . . | К | 18÷26 | (12) То же |
| (13) Паровичный спекающийся . . | ПС | 12÷18 | (12) То же |
| (14) Тощий . . . . . . . . . . . | Т | (15) Менее 17 | (16) Порошкообразный или слипшийся |

Note. Carbon/coals witn the output/yield cf volatile components $V^{r}$-42-44o/o can te related tc trand G only with heat of combustion of their combustible mass $Q_{6}^{r}$ nct tc exchange 790C kcal/kg.

Key: (1). Designation cf brands/marks. (2). Designation. (3). Output/yield of volatile substances to ccmbustible mass, o/o. (4). Characteristic of nonvclatile remainder/residue. (5). Long-flame. (5a). It is more. (6). Fcwder-like or fixing. (7). Gas. (8). Sintered, alloyed, scmetimes distended (loose). (9). Steam fatty/greasy. (10). Sintered, alloyed, dense cr moderately dense. (11). Coke. (12). Then. (13). Steam sintering. (14). Lean. (15). It is less. (16). Powder-like or tecoming husky itself.

Table 2-3. Classificaticn of stoneware and brcwn coal according to the size/dimension of pieces.

| (1) Наименование класса | (2) Условное обозначение класса | (3) Размер кусков, мм |
|---|---|---|
| (4) Крупный | К | 50÷100 |
| (5) Орех | О | 25÷50 |
| (6) Мелкий | М | 13÷25 |
| (7) Семечко | С | 6÷13 |
| (8) Штыб | Ш | (10) Менее 6 |
| (9) Рядовой | Р | (11) Не ограничен |

Note. To the desiçnaticn cf class and tc its conventional designations is assigned the name cf brand/mark, for example: brown large/coarse - BK, gas nut - GC, the mildly sintered tail - SSSh, etc.

With the delivery cf carbon/ccals of brands D. G. PS, ⌐ and SS for the combustion in the dustlike state, and also with the increased humidity of coals and the screening of brcwn ccal, it is mutual classes S and Sh is isclated class with the size/dimension of pieces of less than 13 mm, conditicnally designated SSh (seed with the tail).

With the increased humidity cf brown coal of instead of classes M and SSh is separated the class with the pieces of less than 25 mm - BMSSh (brown fine/small with the seed and the tail).

With small cutput/yield cf brcwn coal cf class BO is separated

class with the size/dimension of pieces 13-50 mm - BOM (brown nut with the fine/small).

The size/dimension of the pieces of the run-of-the-mine coal, obtained in an open manner, must not exceed 300 mm.

Key: (1). Name of class. (2). Conventional designations of class. (3). Size/dimension of pieces, mm. (4). Large. (5). Nut. (6). Fine/small. (7). Seed. (8). Tail. (9). Private. (10). It is less. (11). It is unconfined.

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Oxidized coals are characterized by the full/total/complete or partial loss of the sinterability (on leaving of volatile components $V^{r}$ = 17-40o/o, with which unoxidized coals they completely possess this property). All oxidized carbon/coals possess the lowered/reduced (sometimes on 1000-2000 kcal/kg) heat of combustion $Q_{b}^{c}$ and the lowered/reduced (with the strong degree of oxidation) content of hydrogen. With rare exception they possess the lowered/reduced mechanical strength and the increased tendency toward the oxidation and the spontaneous combustion.

2-15. Tables 2-3 and 2-4 give established/installed by standards

classification of brcwr and ccals, and also anthracite according to size/dimension of pieces.

2-E. Gaseous fuel.

2-16. Gaseous fuel is mixture of combustible and non-burning gases, which contains certain quantity cf admixtures/impurities in the form of water vapors, resin and dust.

2-17. Composition of gaseous fuel is assigned in percentages by volume, and all calculations relate to ncrmal cubic meter of dry gas (with 760 mm Hg and 0°C). The impurity ccntent of water vapors, resin, dust) is assigned in g/nm³ cf dry gas.

2-18. Heat of combustion cf gaseous fuel is calculated according tc formula of mixing

$$Q_n^c = 0{,}01\,[Q_{H_2S}H_2S + Q_{CO}CO + Q_{H_2}H_2 + \Sigma(Q_{C_mH_n}C_mH_n)] \quad \text{by kcal/nm}^3 \qquad (2\text{-}U9)$$

where $Q_{H_2S}$, $Q_{CO}$ and so forth - heat of combusticns cf separate gases, given in Table 2-5, kcal/nm³.

With the content in the fuel/propellant cf small a quantity (to 3o/o) of unsaturated hydrocarbcns cf unknown ccmposition they are

accepted as those consisting of ethylene ($C_2H_4$). For the gas of coke ovens Q. of the unsaturated hydrocarbons of the unknown composition is assumed equal to 17000 kcal/nm³.

2-19. Different gaseous fuels have following special features/peculiarities.

The blast-furnace gas before the admission to the user undergoes cooling and preliminary dusting in the scrubbers or the disintegrators. To user is supplied the gas, saturated with moisture, with the dust content 0.1-1.0 g/nm³ (scrubber purification) and 0.01-0.3 g/nm³ (purification in the disintegrators). The uncleaned blast-furnace gas contains dust 7-12 g/nm³; the carbon content in dust 3-5o/o. Blast-furnace gas with the melting of ferrosilicon contains a considerably larger quantity of dust, and with the dry method of purification, calculated for the common gas, the dust content of gas is higher. There is no resin in the gas virtually.

Generator gas from the large/coarse cake fuel/propellant after cooling and purification is supplied to user by the saturated water vapor with 25-40°C and contains the traces of dust, and gas from the wood and the upper peat - also the vapor of acetic acid - 7-17 g/nm³. Resin content in it of 0-10 g/nm³. Generator gas from the fine-grained fuel/propellant during the gasification in that weighed layer can be given to user with temperature of 150-250°C.

Table 2-4. Classificaticn oi donets anthracite according to the size/dimension of pieces.

| (1) Наименование класса | (2) Условное обозначение класса | (3) Размер кусков, мм |
|---|---|---|
| (4) Антрацит плитный | АП | (5) Более 100 |
| " (6) кулак | АК | 50÷100 |
| " (7) орех | АО | 25÷50 |
| " (8) мелкий | АМ | 13÷25 |
| " (9) семечко | АС | 6÷13 |
| " (10) штыб | АШ | (12) Менее 6 |
| " (11) рядовой (13) (без плиты) | АРШ | (12) Менее 100 |

Note. For the separate mines/shafts can be established/installed the issue of class AP with the size/dimensicn of pieces of mcre than 75 mm and classes AK with the size/dimensicn cf pieces 25-75 mm.

With the sorting cf dry anthracite can be isolated additional class - "anthracite tocth" - AZ with the size/dimension of pieces 3-6 mm; in this case for the class ATs is established/installed the size/dimension of pieces of less than 3 mm. Scmetimes with the high driving in humidity is allowed/assumed the dispatch of anthracite cf class ASSh with the size/dimensicn cf pieces cf less than 13 mm.

Key: (1). Designation cf class. (2). Conventicnal designaticns of class. (3). Size/dimensicn cf pieces, mm. (4). Anthracite (plate. (5). It is more. (6). kulak. (7). nut. (8). fine/small. (9). seed. (10). tail. (11). Private. (12). It is less. (13). (without plate/slab).

Table 2-5. Characteristics of the gases, which form part of gaseous fuel.

| (1) Наименование газа | (2) Обозначение | (3) Удельный вес $\gamma$, кг/нм³ | (4) Теплота сгорания низшая $Q_н$, ккал/нм³ |
|---|---|---|---|
| (5) Водород | $H_2$ | 0,090 | 2 579 |
| (6) Азот элементарный | $N_2$ | 1,251 | — |
| (7) Азот воздуха (с примесью аргона) | $N_2$ | 1,257 | — |
| (8) Кислород | $O_2$ | 1,428 | — |
| (9) Окись углерода | $CO$ | 1,250 | 3 018 |
| (10) Углекислота | $CO_2$ | 1,964 | — |
| (11) Сернистый газ | $SO_2$ | 2,858 | — |
| (12) Сероводород | $H_2S$ | 1,520 | 5 585 |
| (13) Метан | $CH_4$ | 0,716 | 8 555 |
| (14) Этан | $C_2H_6$ | 1,342 | 15 226 |
| (15) Пропан | $C_3H_8$ | 1,967 | 21 795 |
| (16) Бутан | $C_4H_{10}$ | 2,593 | 28 338 |
| (17) Пентан | $C_5H_{12}$ | 3,218 | 34 890 |
| (18) Этилен | $C_2H_4$ | 1,251 | 14 107 |
| (19) Пропилен | $C_3H_6$ | 1,877 | 20 541 |
| (20) Бутилен | $C_4H_8$ | 2,503 | 27 111 |
| (21) Бензол | $C_6H_6$ | 3,485 | 33 528 |

Note. During calculation $\gamma$ and $Q_н$ the volume of the gram-molecule of gas is accepted equal to 22.41 l (as for the perfect gas).

Key: (1). Designation of gas. (2). Designation. (3). Specific gravity/weight kg/nm³. (4). Heat of combustion lowest kcal/nm³. (5). Hydrogen. (6). Nitrogen elementary. (7). Nitrogen of air (with admixture/impurity of argon). (8). Oxygen. (9). Carbon monoxide. (10). Carbonic acid. (11). Sulfur dioxide. (12). Hydrogen sulfide. (13). Methane. (14). Ethane. (15). Propane. (16). Butane. (17). Pentane. (18). Ethylene. (19). Propylene. (20). Butylene. (21). Benzene.

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Dust content in this gas 10-15 g/nm³, resin - 1-1.5 g/nm³, acetic acid (milling peat) - traces, water vapors (with the humidity of fuel/propellant 32-37o/o - 250-300 g/nm³. During scrubber scrubbing of gas contains dust 0.5-1.0 g/nm³, resins - traces, water vapors 30-60 g/nm³.

Gas of air blasting, which is withdrawal/departure during the process of obtaining water gas, leaves the gas generator with temperature of 500-600°C and contains 16-32 g/nm³ of dust and 13-40 g/nm³ of water vapors. Lowest heat of combustion of dust 4200-6000 kcal/kg.

Gas of coke ovens, as a rule, is forwarded to user after purification from resin, benzene, naphthalene and ammonia ("opposite gas"). This gas contains resins and dust traces, benzene - 4 g/nm³. The moisture content of gas answers its saturation at 25-35°C. Crude gas contains benzyl 27-32 g/nm³ and traces of resin, naphthalene and ammonia.

The natural gases, supplied to user, dust do not contain. Their

moisture content depends from the method of dehydration to the admission into the gas pipe and at the places of yield can strongly oscillate. During the supplying of gas to the great distances the moisture from it is removed and moisture content it it is possible to consider corresponding to saturation with 10°C.

2-C. Mixtures of fuels/propellants.

2-20. In the case of combusting mixture of two solid or liquid propellants, prescribed/assigned by parts by weight (g' - part by weight of one of fuels/propellants in mixture), heat of combustion 1 kg of mixture is calculated according to formula

$$Q_{\text{н}}^{р} = Q_{\text{н}}^{р'} g' + Q_{\text{н}}^{р''}(1-g') \quad \text{kcal/kg.} \qquad (2\text{-}10)$$

2-21. If mixture is prescribed/assigned not in parts by weight, but in shares of heat release of each fuel/propellant (q' - fraction/portion of one of fuels/propellants), then for transition to parts by weight serves formula

$$g' = \frac{q' Q_{\text{н}}^{р''}}{q' Q_{\text{н}}^{р''} + (1-q') Q_{\text{н}}^{р'}}. \qquad (2\text{-}11)$$

2-22. During combustion of mixture of solid or liquid propellant with vapor calculation for convenience arbitrarily is conducted not on 1 kg of burned mixture of fuels/propellants, but on 1 kg of solid or liquid propellant taking into account quantity of gas (nm³), which

falls on 1 kg.

In this case conditional heat of combustion of the mixture of fuels/propellants with x nm³ of gas on 1 kg of solid or liquid propellant is calculated according to the formula

$$Q_n^p = Q_n^{p\prime} + xQ_n^{p\prime\prime} \quad \text{kcal/kg.} \quad (2\text{-}12)$$

where $Q_n^{p\prime}$ and $Q_n^{p\prime\prime}$ respectively designate the lowest heat of combustion of the combustion of solid (or liquid) propellant, kcal/kg, and gas, kcal/nm³.

If mixture is prescribed/assigned in the fractions/portions of the heat release of each fuel/propellant - the fraction/portion of solid or liquid propellant in total heat release q' and a fraction/portion of gas (1-q'), the quantity of normal cubic meters of gas, which falls on 1 kg of solid or liquid propellant, comprises:

$$x = \frac{1-q'}{q'} \cdot \frac{Q_n^{p\prime}}{Q_n^{p\prime\prime}} \quad \text{nm}^3\text{/kg.} \quad (2\text{-}13)$$

2-D. Design characteristics of fuel/propellant.

2-23. For selection of design characteristics of fuel/propellant designed assignment must contain following indications:

for anthracite, stoneware and brown coal and schists - designation of deposit, brand/mark and class according to size/dimension of pieces;

for withdrawals/departures of enrichment of carbon/coals - deposit and brand/mark of enriched carbon/coal and method of enrichment (dry, wet);

for peat - method of yield (cake, milling);

for wood fuel/propellant - sizes/dimensions of pieces; for wood waste - character of production from which are obtained withdrawals/departures;

for petroleum residue - brand/mark and sulfur content;

for the artificial gaseous fuel - form of gas, initial fuel/propellant, method of obtaining and scrubbing of gas;

for the natural gaseous fuel - region of yield, character of deposit (natural-gas or purely gas wells).

In view of the fact that the impurity content in the gaseous fuel, and also temperature and pressure, with which the gas proceeds to user, are subjected to considerable fluctuations, these values for the specific cases must be specially refined.

2-24. In RN 2-01 and 2-02 are given design characteristics of basic forms and brands/marks of consumed by Soviet power engineering fuel/propellant. The corrected values cannot be considered as the permanent and solidly established/installed norms. These are some average numbers, which characterize the fuel/propellant, which considerably differs by its composition and quality both on the separate mines/shafts, the peat mining enterprises, etc. and on the time. The characteristics of solid fuel relate in essence to the series unenriched and unscreened fuel/propellant, with exception of screened anthracite of Donbass.

Table 2-6. Moisture content of the saturated gas.

| (1) Температура, °C | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 |
|---|---|---|---|---|---|---|---|---|---|---|
| (2) Влагосодержание на 1 $нм^3$ сухого газа d, $г/нм^3$ | 5,0 | 10,1 | 19,4 | 35,9 | 64,6 | 114 | 202 | 370 | 739 | 1 950 |

Key: (1). Temperature. (2). Moisture content on 1 $nm^3$ of dry gas d, $g/nm^3$.

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Besides the average data, in RN 2-01 are given fundamental characteristics $W^p$ and $A^c$ of the solid fuel of the maximally lowered/reduced quality, the possibility more or less prolonged admission of which should be considered during the design of separate aggregates/units or enterprises.

2-25. During thermal design of boiler aggregates/units design characteristics of fuel/propellant are accepted, as a rule, on RN 2-01 and 2-02. The acceptance of other characteristics is allowed/assumed with a sufficient proof only in the calculations of the aggregates/units, intended for the concrete/specific/actual objects.

Changes of the propellant properties within the limits,

indicated in Table 2-7, lead to such change in the basic results of the thermal design of aggregate/unit, which is within the limits of the precision/accuracy of calculation. Therefore, if the assigned characteristics (separate or somewhat simultaneously) change in comparison with the tabulated data or these accepted earlier for calculating this aggregate/unit to the values, which do not exceed indicated by Table 2-7, recalculation by the fuel/propellant of the changed characteristics to produce one ought not.

2-26. For calculating boiler aggregate/unit during combustion of fuel/propellant, not led in SN 2-01 and 2-02, design characteristics must be established/installed on the basis of analysis specially for this purpose of selected on appropriate commands tests/samples.

The results of analysis are divided into the following classes, arranged/located in descending order of the reliability of their use for the characteristic of commercial fuel/propellant.

1. Analyses of commercial tests/samples (calculated, stockpile, operational).

2. Analyses of sheet tests/samples from effective faces, drifts and so forth, etc.

3. Analyses of tests/samples from prospectings (bore pits, galleries, etc.).

4. Analyses of borehole (core) tests/samples.

Accepted for the establishment of design characteristics of fuel/propellant analyses must satisfy the following minimum requirements:

a) heat of combustion must be determined in calorimeter.

b) the limits of the fluctuations of the heat of combustion of combustible mass $Q^{г}_{н}$ or $Q^{г}_{н}$ the different batches of fuel/propellant or during the different periods of time must not exceed 150-200 kcal/kg.

c) during testing of the conformity of the prescribed/assigned elementary composition to the heat of combustion of combustible mass by Mendeleyev's formula

$$Q^{г}_{н} = 81\,C^{г} + 246\,H^{г} - 26\,(O - S)^{г} \quad \text{kcal/kg} \qquad (2\text{-}14)$$

the latter must not give disagreement with calorimetric determination $Q^{г}_{н}$ more than on 150 kcal/kg for the fuels/propellants with $A^{c} \leq 25\%$ and 200 kcal/kg for the fuels/propellants with $A^{c} > 25\%$. These disagreements

in the first case (when $A^c < 25\%$) can be to that and other sides, and the secondly (when $A^c > 25\%$) the results of calculation according to Mendeleyev's formula must be above $Q^c_\delta$ on the calorimeter.

For the comparison of different tests/samples all data in ash content and content of sulfur ($S_{o6}$, $S_{cm}$, $S_{s}$) must be converted to the dry mass, and by the elementary composition, the heat of combustion and the output/yield of volatile components - to the combustible mass. As a result of this comparison must be determined the design characteristics of fuel/propellant.

The content of working moisture ($W^p$) must be accepted in essence on the commercial and sheet tests/samples, if there is confidence, that the initial humidity of tests/samples was preserved with their finishing and tests/samples were airtightly packed with their delivery/procurement into the laboratory. In the absence of this confidence calculated values $W^p$ must be accepted on the moisture capacity of the large/coarse pieces of carbon/coal $W_{макс}$.

Ash content $A^c$, content of sulfur $S^c_{o6}$, $S^c_{cm}$, $S^c_s$ and melting point of ash must be determined in essence on the commercial tests/samples.

Table 2-7. The standard deviations of propellant properties.

| (1) Наименование характеристики | (2) Обозначение | (3) Размерность | (4) Допустимые отклонения | | |
|---|---|---|---|---|---|
| | | | (5) Тощие угли и антрациты | (6) Каменные угли | (7) Бурые угли |
| (8) Влажность на рабочую массу | $W^p$ | % | 2 | 3 | 4 |
| (9) Зольность на сухую массу | $A^{c\bullet 1}$ | % | 8 | 9 | 10 |
| (10) Содержание углерода на горючую массу | $C^г$ | % | 8 | 7 | 6 |
| » (11) водорода | $H^г$ | % | ←0,8→ | | |
| » (12) кислорода | $O^г$ | % | ←2,5→ | | |
| » (13) серы | $S^г_{op+к}$ | % | (14) Без ограничений | | |
| (15) Теплота сгорания низшая на горючую массу | $Q^г_н$ | (16) ккал/кг | 240 | 210 | 180 |

Key: (1). Designation of characteristic. (2). Designation. (3). Dimensionality. (4). Standard deviations. (5). Lean coal and anthracite. (6). Coals. (7). Brown coal. (8). Humidity to working mass. (9). Ash content to dry mass. (10). Carbon content to combustible mass. (11). hydrogen. (12). oxygen. (13). sulfur. (14). Without limitations. (15). Heat of combustion lowest to combustible mass. (16). kcal/kg.

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FOOTNOTE 1. Calculated ash content must not exceed value $A^c_{макс}$ indicated in RN 2-01. ENDFOOTNOTE.

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For obtaining remaining characteristics ($W^p$, $C^г$, $H^г$, $N^г$, $O^г$, $S^г_{op}$, $Q^г_н$, $V^г$. the characteristic of nonvolatile remainder/residue) can be taken into

consideration the data of the analyses of the tests/samples of all four classes.

2-27. For calculating boiler aggregate/unit on fuel/propellant for which characteristics are given in RN 2-01, but prescribed/assigned ash content or humidity differs from tabulated data of RN 2-01 by values, it is more than tolerances, given in Table 2-7, design characteristics of fuel/propellant are determined by indications paragraphs 2-06 and 2-07 by method of recalculation of tabular values of composition and heat of combustion, if only taken design characteristics of ash content $A^c$ does not exceed $A^c_{\text{макс}}$. indicated in RN 2-01.

2-28. When design characteristics of fuel/propellant are accepted not on RN 2-01 or 2-02, their selection must be produced under management/manual or by consultation of specialized organization.

Chapter Three.

# PHYSICAL CHARACTERISTICS UTILIZED IN THE THERMAL DESIGN OF BOILER UNITS.

3-01. During determination of heat capacity of gases volume of mole was received equal to 22.41 $nm^3$ (on perfect gas).

Heat capacity of air and gases, entering the combustion products, are given in Table 3-1.

The heat capacity of humid air $c_в$ is calculated with the moisture content 10 g on 1 kg of dry air and is related to 1 $nm^3$ of dry air. With other moisture content d g/kg the heat capacity of air is calculated from the formula

$$c_в = c_{c.в} + 0{,}0016 d c_{H_2O} \quad kcal/nm^3\ deg \qquad (3\text{-}01)$$

where $c_{c.в}$ and $c_{H_2O}$ - heat capacity of dry air and water vapor.

The heat capacities of solid fuels, petroleum residue, ash and combustible gases are given in 5N 3-01.

3-02. For combustion products whose pressure in boiler aggregates/units it is small it differs from atmospheric, are given kinematic viscosity coefficients $\nu$ $m^2/s$, while for vapor and water - coefficients of dynamic viscosity $\mu$ kg $s/m^2$.

Table 3-1. Average/mean heat capacity of the air and gases from 0 to t°C, kcal/nm³ deg.

| t, °C | $c_{CO_2}$ | $c_{N_2}$ | $c_{O_2}$ | $c_{H_2O}$ | $c_{c.в}$ | $c_{в}$ |
|---|---|---|---|---|---|---|
| 0 | 0,3821 | 0,3092 | 0,3119 | 0,3569 | 0,3098 | 0,3150 |
| 100 | 0,4061 | 0,3095 | 0,3147 | 0,3595 | 0,3106 | 0,3163 |
| 200 | 0,4269 | 0,3104 | 0,3189 | 0,3636 | 0,3122 | 0,3181 |
| 300 | 0,4449 | 0,3121 | 0,3239 | 0,3684 | 0,3146 | 0,3206 |
| 400 | 0,4609 | 0,3144 | 0,3290 | 0,3739 | 0,3174 | 0,3235 |
| 500 | 0,4750 | 0,3171 | 0,3339 | 0,3797 | 0,3207 | 0,3268 |
| 600 | 0,4875 | 0,3201 | 0,3384 | 0,3857 | 0,3240 | 0,3303 |
| 700 | 0,4988 | 0,3233 | 0,3426 | 0,3920 | 0,3274 | 0,3338 |
| 800 | 0,5090 | 0,3265 | 0,3463 | 0,3984 | 0,3306 | 0,3371 |
| 900 | 0,5181 | 0,3295 | 0,3498 | 0,4050 | 0,3338 | 0,3403 |
| 1 000 | 0,5263 | 0,3324 | 0,3529 | 0,4115 | 0,3367 | 0,3433 |
| 1 100 | 0,5338 | 0,3352 | 0,3557 | 0,4180 | 0,3395 | 0,3463 |
| 1 200 | 0,5407 | 0,3378 | 0,3584 | 0,4244 | 0,3422 | 0,3490 |
| 1 300 | 0,5469 | 0,3404 | 0,3608 | 0,4306 | 0,3447 | 0,3517 |
| 1 400 | 0,5526 | 0,3427 | 0,3631 | 0,4366 | 0,3470 | 0,3542 |
| 1 500 | 0,5578 | 0,3449 | 0,3653 | 0,4425 | 0,3492 | 0,3565 |
| 1 600 | 0,5626 | 0,3470 | 0,3673 | 0,4481 | 0,3513 | 0,3587 |
| 1 700 | 0,5671 | 0,3490 | 0,3693 | 0,4537 | 0,3532 | 0,3607 |
| 1 800 | 0,5712 | 0,3508 | 0,3712 | 0,4589 | 0,3551 | 0,3625 |
| 1 900 | 0,5750 | 0,3525 | 0,3730 | 0,4639 | 0,3568 | 0,3644 |
| 2 000 | 0,5785 | 0,3541 | 0,3748 | 0,4688 | 0,3585 | 0,3661 |
| 2 100 | 0,5818 | 0,3557 | 0,3764 | 0,4735 | 0,3600 | 0,3678 |
| 2 200 | 0,5848 | 0,3571 | 0,3781 | 0,4779 | 0,3615 | 0,3693 |
| 2 300 | 0,5876 | 0,3585 | 0,3797 | 0,4822 | 0,3629 | 0,3708 |
| 2 400 | 0,5902 | 0,3598 | 0,3813 | 0,4864 | 0,3643 | 0,3722 |
| 2 500 | 0,5926 | 0,3610 | 0,3828 | 0,4903 | 0,3655 | 0,3735 |

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Kinematic viscosity coefficient for the vapor and the water is determined as follows:

$$\nu = 9{,}81 \mu v \quad m^2/s \qquad (3\text{-}02)$$

where specific volumes v m³/kg are taken on the tables of appendix II.

3-03. Coefficients of kinematic viscosity/ductility/toughness of

air and flue gases of average/mean composition at pressure 760 mm Hg and temperatures of 0-1600°C are represented in Table 3-2.

The composition of flue gases is characterized by the volume fractions of water vapors and carbonic acids $r_{H_2O}$ and $r_{CO_2}$ equal to the partial pressures of these gass at the total pressure 1 atm(ats.); the average/mean composition of gases corresponds $r_{H_2O}=0{,}11$ and $r_{CO_2}=0{,}13$

The deviation of the kinematic viscosity coefficients of the products of the complete combustion, which have the composition, different from the average, is determined mainly by the content of water vapors.

In Fig. 1a is given factor $M_\nu=\frac{\nu}{\nu_r}$ determined in depending on $r_{H_2O}$ and the temperature of gases.

The kinematic viscosity coefficient of flue gases of the prescribed/assigned composition is determined from the formula

$$\nu=\nu_r M_\nu \quad m^2/s. \qquad (3\text{-}03)$$

3-04. Coefficients of dynamic viscosity of water and water vapor at pressures 1-400 kgf/cm² and temperatures 0-700°C, and also on line of saturation, are given in Table 3-3.

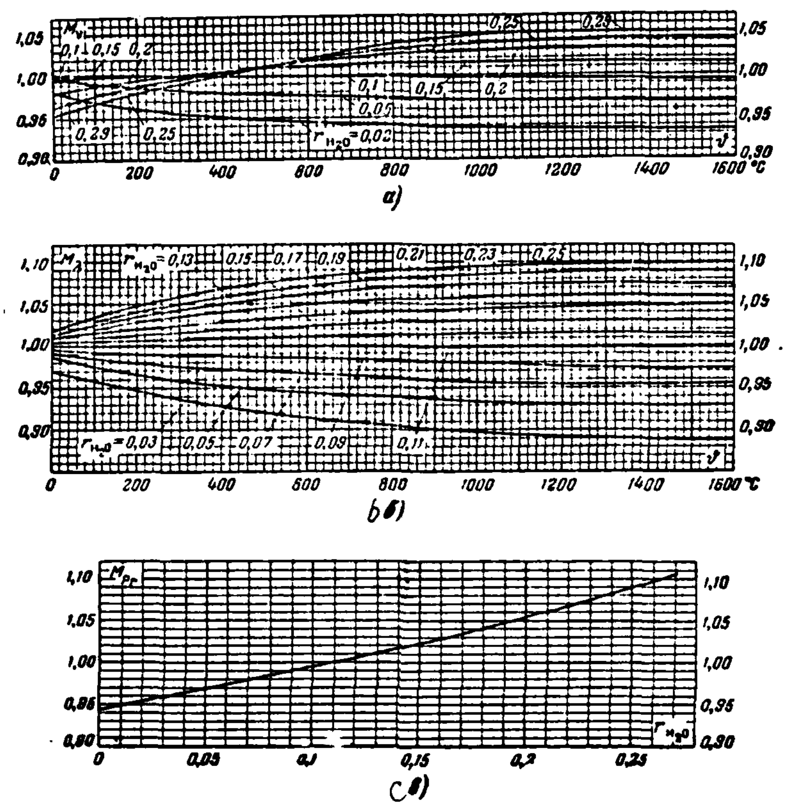


Fig. 1. Corrections for the recalculation of the physical characteristics of flue gases of the average/mean composition: a) correction $M_\nu$; b) correction $M_\lambda$; c) correction $M_{Pr}$

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3-05. Coefficient of thermal conductivity of air and flue gases of average/mean composition $(r_{H_2O} = 0.11$ and $r_{CO_2} = 0.13)$ for temperatures of

C-1600°C they are represented in Table 3-2.

Like viscosity/ductility/toughness, thermal conductivity of the products of the complete combustion depend mainly on the content of water vapors. Fig. 1b gives coefficient $M_\lambda = \frac{\lambda}{\lambda_r}$, determined in depending on $r_{H_2O}$ and the temperature of gases.

The coefficient of the thermal conductivity of flue gases of the prescribed/assigned composition is calculated from the formula

$$\lambda = \lambda_r M_\lambda \text{ kcal/m hour deg.} \quad (3\text{-}04)$$

3-06. Coefficients of thermal conductivity of water and water vapor for pressures 1-400 kgf/cm² and temperatures of 0-700°C, and also on line of saturation, they are represented in Table 3-4.

3-07. Criterion of physical properties

$$Pr = 3600 \frac{\nu c_p \gamma}{\lambda}. \quad (3\text{-}05)$$

where $c_p$ - true heat capacity, kcal/kg deg; $\gamma$ - specific gravity/weight, kg/m³.

Its values for the air at a pressure 1 atm (abs.) virtually do not depend on temperature and for interval of C-1600°C can be accepted Pr=0.71.

3-08. Value of criterion Pr of flue gases depends on temperature and content of water vapors in mixture. Values $Pr_t$ for the flue gases of average/mean composition (the volume fraction of triatomic gases $r_{H_2O}=0.11$ and $r_{CO_2}$ =0.13) at the pressure 760 mm Hg for temperatures of 0-1600°C are given in Table 3-4.

Fig. 1c gives the graph/diagram of the dependence of coefficient $M_{Pr}=\frac{Pr}{Pr_t}$ on the volume fraction of water vapors $r_{H_2O}$. For the flue gases, which differ from average/mean composition, Pr is calculated from the formula

$$Pr=Pr_t\,M_{Pr}. \qquad (3\text{-}06)$$

3.09. Values Pr of water and water vapor for pressures 1-400 kgf cm² and temperature of 0-700°C, and are also on line of saturation given in Table 3-5.

3-10. For boilers, which work with supercharging/pressurization under pressure, which exceeds 1.05 atm(abs.), kinematic viscosity coefficients of gases it is determined from formula

$$\nu_p=\frac{\nu}{p} \quad m^2/s \qquad (3\text{-}07)$$

where p - pressure of flue gass, atm(abs.).

Heat capacity, coefficient of thermal conductivity and criterion of the physical properties of gases are accepted for the region of the pressures which can occur in the boiler flues (including of high-pressure steam generators), not depending on the pressure.

3-11. Specific volumes and enthalpy of water and water vapor are given in tables of appendix II.

3-12. Coefficients of viscosity/ductility/toughness and thermal conductivity, and also value of criterion Pr for gaseous fuels are given in Table 3-6. They can be used for determining of the characteristics of other, close in composition, mixtures of gases.

3-13. Physical characteristics of petroleum residue are given in RN 3-02.

Table 3-2. Physical characteristics of air and flue gases of average/mean composition.

| $t$, °C | (1) Воздух | | (2) Дымовые газы среднего состава | | |
|---|---|---|---|---|---|
| | $\nu\cdot10^6$, $м^2/сек$ (3) | $\lambda\cdot10^2$, ккал/м час град (4) | $\nu_г\cdot10^6$, $м^2/сек$ (3) | $\lambda_г\cdot10^2$, ккал/м час град (4) | $Pr_г$ |
| 0 | 13,3 | 2,10 | 12,2 | 1,96 | 0,72 |
| 100 | 23,0 | 2,76 | 21,5 | 2,69 | 0,69 |
| 200 | 34,8 | 3,38 | 32,8 | 3,45 | 0,67 |
| 300 | 48,2 | 3,96 | 45,8 | 4,16 | 0,65 |
| 400 | 63,0 | 4,48 | 60,4 | 4,90 | 0,64 |
| 500 | 79,3 | 4,94 | 76,3 | 5,64 | 0,63 |
| 600 | 96,8 | 5,36 | 93,6 | 6,38 | 0,62 |
| 700 | 115 | 5,77 | 112 | 7,11 | 0,61 |
| 800 | 135 | 6,17 | 132 | 7,87 | 0,60 |
| 900 | 155 | 6,56 | 152 | 8,61 | 0,59 |
| 1 000 | 178 | 6,94 | 174 | 9,37 | 0,58 |
| 1 100 | 199 | 7,31 | 197 | 10,1 | 0,57 |
| 1 200 | 223 | 7,67 | 221 | 10,8 | 0,56 |
| 1 300 | — | — | 245 | 11,6 | 0,55 |
| 1 400 | 273 | 8,58 | 272 | 12,4 | 0,54 |
| 1 500 | — | — | 297 | 13,2 | 0,53 |
| 1 600 | 328 | 9,27 | 323 | 14,0 | 0,52 |

Key: (1). Air. (2). Flue gases of average/mean composition. (3). $m^2/s$. (4). kcal/m hour deg.

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Table 3-3. Coefficients of dynamic viscosity $\mu \cdot 10^6$ kg s/m², water and water vapor.

| (1) p, kg/cm² / t, °C | 1 | 20 | 40 | 60 | 80 | 100 | 150 | 200 | 250 | 300 | (2) Вода (4) на кривой насыщения | (3) Пар (4) на кривой насыщения |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 182 | 182 | 182 | 181 | 181 | 181 | 180 | 179 | 178 | 176 | 182,3 | 0,84 |
| 10 | 133 | 133 | 133 | 133 | 133 | 132 | 132 | 132 | 131 | 131 | 133,1 | 0,87 |
| 20 | 102 | 102 | 102 | 102 | 102 | 102 | 102 | 102 | 102 | 102 | 102,4 | 0,91 |
| 30 | 81,7 | 81,7 | 81,8 | 81,8 | 81,8 | 81,8 | 81,9 | 81,9 | 82,0 | 82,1 | 81,7 | 0,95 |
| 40 | 66,6 | 66,6 | 66,6 | 66,7 | 66,8 | 66,8 | 66,9 | 67,0 | 67,1 | 67,3 | 66,6 | 0,99 |
| 50 | 56,0 | 56,0 | 56,1 | 56,1 | 56,2 | 56,2 | 56,3 | 56,5 | 56,6 | 56,8 | 56,0 | 1,02 |
| 60 | 47,9 | 47,9 | 48,0 | 48,0 | 48,1 | 48,1 | 48,2 | 48,4 | 48,6 | 48,8 | 47,9 | 1,06 |
| 70 | 41,4 | 41,4 | 41,5 | 41,5 | 41,6 | 41,6 | 41,7 | 41,9 | 42,0 | 42,2 | 41,4 | 1,10 |
| 80 | 36,2 | 36,2 | 36,3 | 36,3 | 36,4 | 36,4 | 36,5 | 36,7 | 36,8 | 37,0 | 36,2 | 1,14 |
| 90 | 32,1 | 32,1 | 32,2 | 32,2 | 32,3 | 32,3 | 32,4 | 32,6 | 32,7 | 32,9 | 32,1 | 1,18 |
| 100 | 1,22 | 28,8 | 28,9 | 28,9 | 29,0 | 29,0 | 29,1 | 29,3 | 29,4 | 29,6 | 28,8 | 1,22 |
| 110 | 1,26 | 26,4 | 26,5 | 26,5 | 26,6 | 26,6 | 26,7 | 26,9 | 27,0 | 27,2 | 26,4 | 1,27 |
| 120 | 1,30 | 24,2 | 24,3 | 24,3 | 24,4 | 24,4 | 24,5 | 24,7 | 24,8 | 25,0 | 24,2 | 1,31 |
| 130 | 1,34 | 22,2 | 22,3 | 22,3 | 22,4 | 22,4 | 22,5 | 22,7 | 22,8 | 23,0 | 22,2 | 1,35 |
| 140 | 1,38 | 20,5 | 20,6 | 20,6 | 20,7 | 20,7 | 20,8 | 20,9 | 21,0 | 21,2 | 20,5 | 1,38 |
| 150 | 1,42 | 19,0 | 19,1 | 19,1 | 19,2 | 19,2 | 19,3 | 19,4 | 19,5 | 19,7 | 19,0 | 1,42 |
| 160 | 1,46 | 17,7 | 17,8 | 17,8 | 17,9 | 17,9 | 18,0 | 18,1 | 18,2 | 18,4 | 17,7 | 1,46 |
| 170 | 1,50 | 16,6 | 16,7 | 16,7 | 16,8 | 16,8 | 16,9 | 17,0 | 17,1 | 17,3 | 16,6 | 1,50 |
| 180 | 1,54 | 15,6 | 15,7 | 15,7 | 15,8 | 15,8 | 15,9 | 16,0 | 16,1 | 16,3 | 15,6 | 1,54 |
| 190 | 1,58 | 14,7 | 14,8 | 14,8 | 14,9 | 14,9 | 15,0 | 15,1 | 15,2 | 15,4 | 14,7 | 1,59 |
| 200 | 1,62 | 13,9 | 14,0 | 14,0 | 14,1 | 14,1 | 14,2 | 14,3 | 14,4 | 14,6 | 13,9 | 1,63 |
| 210 | 1,66 | 13,3 | 13,4 | 13,4 | 13,5 | 13,5 | 13,6 | 13,7 | 13,8 | 14,0 | 13,3 | 1,67 |
| 220 | 1,70 | 1,72 | 12,8 | 12,8 | 12,9 | 12,9 | 13,0 | 13,1 | 13,2 | 13,4 | 12,7 | 1,72 |
| 230 | 1,75 | 1,76 | 12,2 | 12,3 | 12,3 | 12,4 | 12,5 | 12,6 | 12,7 | 12,9 | 12,2 | 1,77 |
| 240 | 1,79 | 1,80 | 11,7 | 11,8 | 11,8 | 11,9 | 12,0 | 12,1 | 12,2 | 12,4 | 11,7 | 1,81 |
| 250 | 1,83 | 1,84 | 1,86 | 11,3 | 11,3 | 11,4 | 11,5 | 11,7 | 11,8 | 12,0 | 11,2 | 1,86 |
| 260 | 1,87 | 1,88 | 1,91 | 10,9 | 10,9 | 11,0 | 11,1 | 11,2 | 11,3 | 11,5 | 10,8 | 1,92 |
| 270 | 1,91 | 1,92 | 1,95 | 10,5 | 10,5 | 10,6 | 10,7 | 10,8 | 10,9 | 11,1 | 10,4 | 1,97 |
| 280 | 1,96 | 1,97 | 1,99 | 2,02 | 10,1 | 10,2 | 10,3 | 10,4 | 10,5 | 10,7 | 10,0 | 2,03 |
| 290 | 2,00 | 2,01 | 2,03 | 2,06 | 9,7 | 9,8 | 9,9 | 10,0 | 10,1 | 10,3 | 9,6 | 2,10 |

| p, кг/см² (1) / t, °C | 1 | 20 | 40 | 60 | 80 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | Вода (2) на кривой насыщения (4) | Пар (3) на кривой насыщения (4) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 300 | 2,04 | 2,05 | 2,07 | 2,10 | 2,14 | 9,3 | 9,42 | 9,60 | 9,72 | 9,85 | 9,98 | 10,1 | 9,3 | 2,17 |
| 310 | 2,08 | 2,09 | 2,11 | 2,14 | 2,18 | 2,24 | 9,14 | 9,26 | 9,38 | 9,51 | 9,62 | 9,72 | 9,0 | 2,24 |
| 320 | 2,13 | 2,13 | 2,15 | 2,18 | 2,21 | 2,27 | 8,81 | 8,92 | 9,04 | 9,16 | 9,27 | 9,38 | 8,7 | 2,33 |
| 330 | 2,17 | 2,18 | 2,19 | 2,22 | 2,25 | 2,30 | 8,42 | 8,55 | 8,68 | 8,82 | 8,92 | 9,03 | 8,3 | 2,44 |
| 340 | 2,21 | 2,22 | 2,24 | 2,26 | [illegible] | 2,33 | 7,94 | 8,14 | 8,30 | 8,47 | 8,57 | 8,70 | 7,9 | 2,57 |
| 350 | 2,25 | 2,26 | 2,28 | 2,30 | 2,33 | 2,37 | 2,55 | 7,64 | 7,58 | 8,09 | 8,22 | 8,36 | 7,4 | 2,71 |
| 360 | 2,30 | 2,31 | 2,32 | 2,34 | 2,37 | 2,41 | 2,56 | 7,04 | 7,40 | 7,66 | 7,86 | 8,01 | 6,8 | 2,97 |
| 370 | 2,34 | 2,35 | 2,37 | 2,38 | 2,41 | 2,44 | 2,58 | 2,95 | 6,84 | 7,20 | 7,46 | 7,65 | 5,8 | 3,44 |
| 380 | 2,38 | 2,39 | 2,41 | 2,43 | 2,45 | 2,48 | 2,61 | 2,87 | 5,61 | 6,65 | 7,00 | 7,27 | — | — |
| 390 | 2,43 | 2,44 | 2,45 | 2,47 | 2,50 | 2,52 | 2,64 | 2,85 | 3,49 | 5,85 | 6,49 | 6,88 | — | — |
| 400 | 2,47 | 2,48 | 2,50 | 2,51 | 2,54 | 2,57 | 2,67 | 2,85 | 3,24 | 4,60 | 5,77 | 6,39 | — | — |
| 410 | 2,52 | 2,53 | 2,54 | 2,56 | 2,58 | 2,61 | 2,70 | 2,86 | 3,15 | 3,92 | 5,01 | 5,82 | — | — |
| 420 | 2,56 | 2,57 | 2,58 | 2,60 | 2,63 | 2,65 | 2,73 | 2,88 | 3,12 | 3,59 | 4,44 | 5,27 | — | — |
| 430 | 2,61 | 2,61 | 2,62 | 2,64 | 2,66 | 2,69 | 2,77 | 2,90 | 3,11 | 3,47 | 4,03 | 4,81 | — | — |
| 440 | 2,65 | 2,66 | 2,67 | 2,69 | 2,71 | 2,73 | 2,81 | 2,93 | 3,12 | 3,40 | 3,88 | 4,44 | — | — |
| 450 | 2,70 | 2,70 | 2,72 | 2,73 | 2,75 | 2,77 | 2,85 | 2,96 | 3,12 | 3,37 | 3,74 | 4,19 | — | — |
| 460 | 2,74 | 2,75 | 2,76 | 2,77 | 2,79 | 2,82 | 2,89 | 3,00 | 3,14 | 3,35 | 3,67 | 4,03 | — | — |
| 470 | 2,79 | 2,79 | 2,80 | 2,82 | 2,84 | 2,96 | 2,93 | 3,03 | 3,16 | 3,35 | 3,62 | 3,94 | — | — |
| 480 | 2,84 | 2,84 | 2,85 | 2,86 | 2,88 | 2,90 | 2,97 | 3,06 | 3,19 | 3,36 | 3,59 | 3,88 | — | — |
| 490 | 2,88 | 2,88 | 2,89 | 2,91 | 2,92 | 2,94 | 3,01 | 3,10 | 3,22 | 3,37 | 3,58 | 3,83 | — | — |
| 500 | 2,93 | 2,93 | 2,94 | 2,95 | 2,97 | 2,99 | 3,05 | 3,14 | 3,25 | 3,39 | 3,58 | 3,80 | — | — |
| 510 | 2,97 | 2,97 | 2,98 | 3,00 | 3,01 | 3,03 | 3,09 | 3,17 | 3,28 | 3,41 | — | — | — | — |
| 520 | 3,01 | 3,02 | 3,03 | 3,04 | 3,06 | 3,07 | 3,13 | 3,21 | 3,31 | 3,44 | — | — | — | — |
| 530 | 3,06 | 3,06 | 3,07 | 3,09 | 3,10 | 3,12 | 3,18 | 3,25 | 3,35 | 3,47 | — | — | — | — |
| 540 | 3,10 | 3,11 | 3,12 | 3,13 | 3,15 | 3,16 | 3,22 | 3,29 | 3,38 | 3,50 | — | — | — | — |
| 550 | 3,15 | 3,16 | 3,16 | 3,18 | 3,19 | 3,21 | 3,26 | 3,33 | 3,42 | 3,53 | 3,66 | 3,81 | — | — |
| 560 | 3,20 | 3,20 | 3,21 | 3,22 | 3,24 | 3,25 | 3,31 | 3,37 | 3,46 | 3,56 | — | — | — | — |
| 570 | 3,24 | 3,25 | 3,26 | 3,27 | 3,28 | 3,30 | 3,35 | 3,41 | 3,50 | 3,59 | — | — | — | — |
| 580 | 3,29 | 3,29 | 3,30 | 3,31 | 3,33 | 3,34 | 3,39 | 3,46 | 3,53 | 3,63 | — | — | — | — |
| 590 | 3,33 | 3,34 | 3,35 | 3,36 | 3,37 | 3,39 | 3,43 | 3,50 | 3,57 | 3,66 | — | — | — | — |
| 600 | 3,39 | 3,40 | 3,41 | 3,42 | 3,43 | 3,44 | 3,48 | 3,54 | 3,61 | 3,70 | 3,80 | 3,90 | — | — |
| 650 | 3,64 | 3,65 | 3,66 | 3,67 | 3,68 | 3,69 | 3,73 | 3,79 | 3,86 | 3,94 | 4,02 | 4,11 | — | — |
| 700 | 3,90 | 3,91 | 3,92 | 3,93 | 3,94 | 3,95 | 3,99 | 4,05 | 4,12 | 4,20 | 4,28 | 4,35 | — | — |

Key: (1). kg/cm². (2). watar. (3). Steam. (4). in saturation curve.

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Table 3-4. Coefficient cf thermal conductivity λ•10², kcal/m hour deg, water also cf water vapcr.

| p, кг/см² (1) / t, °C | 1 | 20 | 40 | 60 | 80 | 100 | 150 | 200 | 250 | 300 | (2) Вода (4) на кривой насыщения | (3) Пар (4) на кривой насыщения |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 47,4 | 47,4 | 47,5 | 47,5 | 47,6 | 47,7 | 47,8 | 48,0 | 48,2 | 48,4 | 47,4 | — |
| 10 | 49,4 | 49,4 | 49,5 | 49,6 | 49,7 | 49,8 | 50,0 | 50,2 | 50,4 | 50,7 | 49,4 | — |
| 20 | 51,5 | 51,5 | 51,6 | 51,7 | 51,8 | 51,9 | 52,1 | 52,3 | 52,5 | 52,8 | 51,5 | — |
| 30 | 53,1 | 53,1 | 53,2 | 53,3 | 53,4 | 53,5 | 53,7 | 54,0 | 54,2 | 54,5 | 53,1 | — |
| 40 | 54,5 | 54,5 | 54,6 | 51,7 | 54,8 | 54,9 | 55,1 | 55,4 | 55,6 | 55,9 | 54,5 | — |
| 50 | 55,7 | 55,7 | 55,8 | 55,9 | 56,0 | 56,1 | 56,3 | 56,5 | 56,7 | 57,0 | 55,7 | — |
| 60 | 56,7 | 56,7 | 56,8 | 56,9 | 57,0 | 57,1 | 57,3 | 57,5 | 57,7 | 58,0 | 56,7 | — |
| 70 | 57,4 | 57,4 | 57,5 | 57,6 | 57,7 | 57,8 | 58,0 | 58,3 | 58,5 | 58,8 | 57,4 | — |
| 80 | 58,0 | 58,0 | 58,1 | 58,2 | 58,3 | 58,4 | 58,6 | 58,9 | 59,1 | 59,4 | 58,0 | — |
| 90 | 58,5 | 58,5 | 58,6 | 58,7 | 58,8 | 58,9 | 59,1 | 59,4 | 59,6 | 59,9 | 58,5 | — |
| 100 | 2,04 | 58,8 | 58,9 | 59,0 | 59,1 | 59,3 | 59,5 | 59,8 | 60,0 | 60,3 | 58,7 | 2,04 |
| 110 | 2,12 | 58,9 | 59,0 | 59,1 | 59,3 | 59,5 | 59,7 | 60,0 | 60,2 | 60,5 | 58,9 | 2,14 |
| 120 | 2,21 | 59,0 | 59,1 | 59,2 | 59,4 | 59,6 | 59,9 | 60,2 | 60,5 | 60,8 | 59,0 | 2,23 |
| 130 | 2,29 | 59,0 | 59,1 | 59,2 | 59,4 | 59,6 | 59,9 | 60,2 | 60,5 | 60,9 | 59,0 | 2,31 |
| 140 | 2,37 | 58,9 | 59,0 | 59,2 | 59,4 | 59,6 | 59,9 | 60,2 | 60,5 | 60,8 | 58,9 | 2,40 |
| 150 | 2,44 | 58,8 | 59,0 | 59,2 | 59,4 | 59,6 | 59,8 | 60,1 | 60,4 | 60,8 | 58,8 | 2,48 |
| 160 | 2,53 | 58,7 | 58,8 | 58,9 | 59,1 | 59,3 | 59,6 | 59,9 | 60,3 | 60,6 | 58,7 | 2,59 |
| 170 | 2,61 | 58,4 | 58,5 | 58,7 | 58,9 | 59,1 | 59,4 | 59,7 | 60,0 | 60,3 | 58,4 | 2,69 |
| 180 | 2,71 | 58,0 | 58,1 | 58,3 | 58,5 | 58,7 | 59,0 | 59,3 | 59,6 | 60,0 | 58,0 | 2,81 |
| 190 | 2,80 | 57,6 | 57,7 | 57,9 | 58,1 | 58,3 | 58,6 | 58,9 | 59,3 | 59,7 | 57,6 | 2,94 |
| 200 | 2,88 | 57,0 | 57,2 | 57,4 | 57,6 | 57,8 | 58,1 | 58,4 | 58,8 | 59,3 | 57,0 | 3,05 |
| 210 | 2,98 | 56,3 | 56,5 | 56,7 | 56,9 | 57,2 | 57,6 | 58,0 | 58,3 | 58,7 | 56,3 | 3,20 |
| 220 | 3,07 | 3,27 | 55,7 | 55,9 | 56,1 | 56,4 | 56,8 | 57,2 | 57,7 | 58,2 | 55,5 | 3,35 |
| 230 | 3,16 | 3,38 | 54,9 | 55,1 | 55,3 | 55,6 | 56,0 | 56,5 | 56,9 | 57,4 | 54,8 | 3,52 |
| 240 | 3,24 | 3,44 | 54,0 | 54,2 | 54,4 | 54,7 | 55,2 | 55,7 | 56,2 | 56,7 | 54,0 | 3,69 |
| 250 | 3,33 | 3,52 | 3,87 | 53,1 | 53,3 | 53,7 | 54,2 | 54,7 | 55,2 | 55,7 | 53,1 | 3,88 |
| 260 | 3,43 | 3,61 | 3,93 | 52,1 | 52,3 | 52,6 | 53,1 | 53,6 | 54,1 | 54,7 | 52,0 | 4,13 |
| 270 | 3,53 | 3,72 | 4,03 | 50,7 | 51,0 | 51,4 | 52,0 | 52,6 | 53,1 | 53,7 | 50,7 | 4,39 |
| 280 | 3,62 | 3,80 | 4,08 | 4,51 | 49,5 | 50,0 | 50,6 | 51,2 | 51,3 | 52,6 | 49,4 | 4,72 |
| 290 | 3,71 | 3,89 | 4,17 | 4,48 | 48,0 | 48,4 | 49,0 | 49,7 | 50,5 | 51,3 | 48,0 | 5,01 |

Table 3-4 (cont'd).

| (1) p, кг/см² / t, °C | 1 | 20 | 40 | 60 | 80 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | (2) Вода (4) на кривой насыщения | (3) Пар (4) на кривой насыщения |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 300 | 3,80 | 3,95 | 4,23 | 4,60 | 5,14 | 46,6 | 47,3 | 48,0 | 48,6 | 49,2 | 49,6 | 50,1 | 46,4 | 5,39 |
| 310 | 3,91 | 4,08 | 4,34 | 4,69 | 5,17 | 5,8[illegible] | 45,8 | 46,5 | 47,2 | 47,9 | 48,4 | 49,0 | 45,0 | 5,88 |
| 320 | 4,01 | 4,18 | 4,43 | 4,75 | 5,20 | 5,78 | 44,1 | 45,1 | 45,9 | 46,5 | 47,2 | 47,9 | 43,5 | 6,46 |
| 330 | 4,10 | 4,26 | 4,51 | 4,82 | 5,24 | 5,77 | 42,0 | 43,4 | 44,3 | 45,2 | 45,9 | 46,6 | 41,6 | 7,10 |
| 340 | 4,20 | 4,36 | 4,60 | 4,90 | 5,28 | 5,77 | 39,3 | 41,4 | 42,6 | 43,7 | 44,4 | 45,2 | 39,3 | 8,00 |
| 350 | 4,30 | 4,44 | 4,67 | 4,96 | 5,33 | 5,77 | 7,64 | 38,9 | 40,7 | 41,9 | 42,8 | 43,7 | 37,0 | 9,20 |
| 360 | 4,39 | 4,53 | 4,76 | 5,04 | 5,39 | 5,81 | 7,40 | 35,4 | 38,3 | 39,9 | 41,0 | 42,2 | 34,0 | 11,0 |
| 370 | 4,50 | 4,64 | 4,86 | 5,13 | 5,46 | 5,85 | 7,27 | 10,6 | 34,8 | 37,6 | 39,1 | 40,4 | 29,0 | 14,70 |
| 380 | 4,61 | 4,74 | 4,95 | 5,22 | 5,54 | 5,91 | 7,20 | 9,55 | 27,6 | 34,5 | 36,5 | 38,4 | — | — |
| 390 | 4,72 | 4,85 | 5,06 | 5,30 | 5,62 | 5,98 | 7,17 | 9,15 | 14,7 | 29,9 | 33,4 | 36,1 | — | — |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 400 | 4,81 | 4,94 | 5,14 | 5,38 | 5,69 | 6,01 | 7,12 | 8,84 | 12,2 | 22,1 | 29,9 | 33,5 | — | — |
| 410 | 4,91 | 5,04 | 5,24 | 5,48 | 5,76 | 6,08 | 7,12 | 8,61 | 11,2 | 17,2 | 25,3 | 30,5 | — | — |
| 420 | 5,02 | 5,15 | 5,35 | 5,58 | 5,85 | 6,16 | 7,14 | 8,53 | 10,7 | 14,5 | 20,9 | 26,9 | — | — |
| 430 | 5,12 | 5,25 | 5,44 | 5,67 | 5,93 | 6,23 | 7,16 | 8,45 | 10,3 | 13,2 | 17,9 | 23,0 | — | — |
| 440 | 5,23 | 5,36 | 5,54 | 5,77 | 6,01 | 6,31 | 7,20 | 8,38 | 10,1 | 12,4 | 16,0 | 20,1 | — | — |
| 450 | 5,33 | 5,46 | 5,64 | 5,88 | 6,10 | 6,38 | 7,23 | 8,35 | 9,84 | 11,9 | 14,8 | 18,2 | — | — |
| 460 | 5,45 | 5,58 | 5,76 | 5,99 | 6,20 | 6,47 | 7,29 | 8,35 | 9,70 | 11,5 | 14,0 | 16,8 | — | — |
| 470 | 5,56 | 5,69 | 5,87 | 6,09 | 6,29 | 6,56 | 7,35 | 8,34 | 9,62 | 11,3 | 13,5 | 15,8 | — | — |
| 480 | 5,68 | 5,80 | 5,97 | 6,18 | 6,40 | 6,65 | 7,41 | 8,36 | 9,56 | 11,1 | 13,0 | 15,1 | — | — |
| 490 | 5,78 | 5,90 | 6,06 | 6,26 | 6,48 | 6,73 | 7,46 | 8,37 | 9,51 | 10,9 | 12,6 | 14,4 | — | — |
| 500 | 5,88 | 6,00 | 6,16 | 6,35 | 6,57 | 6,81 | 7,52 | 8,39 | 9,46 | 10,8 | 12,3 | 14,0 | — | — |
| 510 | 6,00 | 6,12 | 6,28 | 6,47 | 6,67 | 6,91 | 7,60 | 8,42 | 9,45 | 10,7 | — | — | — | — |
| 520 | 6,11 | 6,22 | 6,38 | 6,57 | 6,77 | 7,00 | 7,67 | 8,47 | 9,41 | 10,6 | — | — | — | — |
| 530 | 6,22 | 6,33 | 6,48 | 6,67 | 6,87 | 7,09 | 7,74 | 8,52 | 9,44 | 10,5 | — | — | — | — |
| 540 | 6,32 | 6,42 | 6,57 | 6,76 | 6,96 | 7,17 | 7,81 | 8,56 | 9,45 | 10,5 | — | — | — | — |
| 550 | 6,44 | 6,54 | 6,69 | 6,88 | 7,06 | 7,28 | 7,90 | 8,62 | 9,48 | 10,5 | 11,6 | 12,9 | — | — |
| 560 | 6,56 | 6,66 | 6,81 | 6,99 | 7,17 | 7,38 | 7,98 | 8,69 | 9,52 | 10,5 | — | — | — | — |
| 570 | 6,68 | 6,78 | 6,92 | 7,09 | 7,28 | 7,49 | 8,07 | 8,77 | 9,56 | 10,5 | — | — | — | — |
| 580 | 6,79 | 6,89 | 7,03 | 7,19 | 7,38 | 7,57 | 8,16 | 8,83 | 9,60 | 10,4 | — | — | — | — |
| 590 | 6,91 | 7,01 | 7,14 | 7,29 | 7,49 | 7,67 | 8,25 | 8,90 | 9,65 | 10,4 | — | — | — | — |
| 600 | 7,03 | 7,13 | 7,26 | 7,42 | 7,60 | 7,79 | 8,34 | 8,99 | 9,70 | 10,4 | 11,5 | 12,4 | — | — |
| 650 | 7,62 | 7,70 | 7,81 | 7,94 | 8,09 | 8,25 | 8,72 | 9,27 | 9,87 | 10,5 | 11,5 | 12,3 | — | — |
| 700 | 8,22 | 8,29 | 8,39 | 8,50 | 8,64 | 8,78 | 9,20 | 9,70 | 10,2 | 10,7 | 11,7 | 12,4 | — | — |

Key: (1). kg/cm². (2). Water. (3). Steam. (4). in saturation curve.

Pages 20-21.

Table 3-5. Criterion of the physical properties Pr for the water and the water vapor.

| t, °C \ p, кг/см² (1) | 1 | 20 | 40 | 60 | 80 | 100 | 150 | 200 | 250 | 300 | (2) Вода, (4) на кривой насыщения | (3) Пар, (4) на кривой насыщения |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 13,7 | 13,6 | 13,6 | 13,5 | 13,5 | 13,4 | 13,3 | 13,1 | 13,0 | 12,8 | 13,7 | — |
| 10 | 9,52 | 9,51 | 9,50 | 9,47 | 9,44 | 9,32 | 9,29 | 9,22 | 9,09 | 8,96 | 9,52 | — |
| 20 | 7,00 | 6,98 | 6,96 | 6,94 | 6,92 | 6,90 | 6,86 | 6,81 | 6,77 | 6,71 | 7,00 | — |
| 30 | 5,41 | 5,41 | 5,40 | 5,39 | 5,37 | 5,35 | 5,33 | 5,29 | 5,27 | 5,22 | 5,41 | — |
| 40 | 4,30 | 4,28 | 4,28 | 4,27 | 4,26 | 4,25 | 4,24 | 4,21 | 4,19 | 4,17 | 4,30 | — |
| 50 | 3,54 | 3,54 | 3,53 | 3,52 | 3,51 | 3,50 | 3,49 | 3,48 | 3,46 | 3,45 | 3,54 | — |
| 60 | 2,98 | 2,97 | 2,97 | 2,96 | 2,96 | 2,95 | 2,94 | 2,93 | 2,92 | 2,91 | 2,98 | — |
| 70 | 2,55 | 2,54 | 2,54 | 2,53 | 2,53 | 2,52 | 2,51 | 2,50 | 2,49 | 2,48 | 2,55 | — |
| 80 | 2,21 | 2,21 | 2,20 | 2,20 | 2,20 | 2,19 | 2,18 | 2,17 | 2,16 | 2,15 | 2,21 | — |
| 90 | 1,95 | 1,95 | 1,94 | 1,94 | 1,93 | 1,93 | 1,92 | 1,92 | 1,91 | 1,91 | 1,95 | — |
| 100 | 1,06 | 1,74 | 1,74 | 1,74 | 1,73 | 1,72 | 1,72 | 1,72 | 1,71 | 1,71 | 1,75 | 1,08 |
| 110 | 1,03 | 1,60 | 1,60 | 1,60 | 1,59 | 1,58 | 1,58 | 1,58 | 1,57 | 1,57 | 1,60 | 1,09 |
| 120 | 1,01 | 1,47 | 1,47 | 1,47 | 1,46 | 1,46 | 1,46 | 1,45 | 1,45 | 1,44 | 1,47 | 1,09 |
| 130 | 0,99 | 1,35 | 1,35 | 1,35 | 1,35 | 1,34 | 1,34 | 1,34 | 1,33 | 1,33 | 1,35 | 1,11 |
| 140 | 0,98 | 1,26 | 1,26 | 1,25 | 1,25 | 1,24 | 1,24 | 1,23 | 1,23 | 1,23 | 1,26 | 1,12 |
| 150 | 0,97 | 1,17 | 1,17 | 1,17 | 1,17 | 1,16 | 1,16 | 1,15 | 1,15 | 1,14 | 1,17 | 1,15 |
| 160 | 0,96 | 1,10 | 1,10 | 1,10 | 1,10 | 1,10 | 1,09 | 1,09 | 1,08 | 1,08 | 1,10 | 1,18 |
| 170 | 0,96 | 1,05 | 1,05 | 1,05 | 1,04 | 1,04 | 1,03 | 1,03 | 1,03 | 1,02 | 1,05 | 1,21 |
| 180 | 0,95 | 1,00 | 1,00 | 1,00 | 1,00 | 0,99 | 0,99 | 0,98 | 0,98 | 0,98 | 1,00 | 1,25 |
| 190 | 0,94 | 0,96 | 0,96 | 0,96 | 0,96 | 0,95 | 0,95 | 0,94 | 0,94 | 0,94 | 0,96 | 1,30 |
| 200 | 0,94 | 0,93 | 0,93 | 0,92 | 0,92 | 0,92 | 0,91 | 0,91 | 0,91 | 0,90 | 0,93 | 1,34 |
| 210 | 0,93 | 0,91 | 0,91 | 0,90 | 0,90 | 0,90 | 0,89 | 0,89 | 0,88 | 0,88 | 0,91 | 1,37 |
| 220 | 0,93 | 1,30 | 0,89 | 0,89 | 0,89 | 0,88 | 0,87 | 0,87 | 0,86 | 0,86 | 0,89 | 1,42 |
| 230 | 0,93 | 1,21 | 0,88 | 0,87 | 0,87 | 0,87 | 0,86 | 0,86 | 0,85 | 0,85 | 0,88 | 1,47 |
| 240 | 0,92 | 1,16 | 0,87 | 0,87 | 0,86 | 0,86 | 0,85 | 0,85 | 0,84 | 0,84 | 0,87 | 1,53 |
| 250 | 0,92 | 1,12 | 1,62 | 0,86 | 0,86 | 0,86 | 0,85 | 0,84 | 0,83 | 0,83 | 0,86 | 1,61 |
| 260 | 0,92 | 1,08 | 1,44 | 0,87 | 0,86 | 0,86 | 0,85 | 0,84 | 0,83 | 0,83 | 0,87 | 1,68 |
| 270 | 0,91 | 1,05 | 1,33 | 0,88 | 0,88 | 0,87 | 0,86 | 0,84 | 0,83 | 0,83 | 0,88 | 1,76 |
| 280 | 0,91 | 1,04 | 1,25 | 1,68 | 0,89 | 0,89 | 0,87 | 0,86 | 0,85 | 0,84 | 0,89 | 1,85 |
| 290 | 0,91 | 1,02 | 1,19 | 1,53 | 0,93 | 0,92 | 0,89 | 0,87 | 0,85 | 0,84 | 0,93 | 1,99 |

| p, кг/см² (1) / t, °C | 1 | 20 | 40 | 60 | 80 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | (2) Вода (4) на кривой насыщения | (3) Пар (4) на кривой насыщения |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 300 | 0,91 | 1,01 | 1,14 | 1,39 | 1,81 | 0,95 | 0,92 | 0,89 | 0,88 | 0,87 | 0,85 | 0,83 | 0,97 | 2,13 |
| 310 | 0,91 | 1,00 | 1,10 | 1,29 | 1,59 | 2,25 | 0,97 | 0,93 | 0,91 | 0,89 | 0,86 | 0,83 | 1,02 | 2,28 |
| 320 | 0,91 | 0,98 | 1,07 | 1,22 | 1,44 | 1,89 | 1,04 | 0,98 | 0,95 | 0,92 | 0,88 | 0,84 | 1,11 | 2,51 |
| 330 | 0,91 | 0,96 | 1,05 | 1,17 | 1,34 | 1,62 | 1,17 | 1,06 | 1,00 | 0,95 | 0,89 | 0,85 | 1,22 | 2,86 |
| 340 | 0,90 | 0,96 | 1,03 | 1,13 | 1,27 | 1,48 | 1,38 | 1,17 | 1,07 | 0,99 | 0,92 | 0,86 | 1,38 | 3,34 |
| 350 | 0,90 | 0,95 | 1,02 | 1,10 | 1,21 | 1,36 | 2,48 | 1,37 | 1,15 | 1,04 | 0,97 | 0,91 | 1,60 | 4,03 |
| 360 | 0,90 | 0,95 | 1,01 | 1,07 | 1,18 | 1,29 | 1,90 | 2,10 | 1,34 | 1,12 | 1,03 | 0,96 | 2,36 | 5,24 |
| 370 | 0,90 | 0,94 | 1,00 | 1,05 | 1,13 | 1,22 | 1,65 | 3,78 | 1,91 | 1,30 | 1,12 | 1,04 | 6,80 | 11,10 |
| 380 | 0,90 | 0,94 | 0,99 | 1,04 | 1,10 | 1,17 | 1,49 | 2,42 | 5,90 | 1,62 | 1,29 | 1,15 | — | — |
| 390 | 0,90 | 0,94 | 0,98 | 1,02 | 1,07 | 1,14 | 1,39 | 1,90 | 4,60 | 2,76 | 1,58 | 1,30 | — | — |
| 400 | 0,90 | 0,93 | 0,97 | 1,01 | 1,05 | 1,11 | 1,32 | 1,66 | 2,67 | 5,22 | 2,01 | 1,49 | — | — |
| 410 | 0,90 | 0,93 | 0,96 | 1,00 | 1,04 | 1,09 | 1,25 | 1,51 | 2,06 | 3,48 | 2,85 | 1,76 | — | — |
| 420 | 0,90 | 0,93 | 0,95 | 0,99 | 1,02 | 1,06 | 1,19 | 1,39 | 1,75 | 2,51 | 3,29 | 2,15 | — | — |
| 430 | 0,90 | 0,92 | 0,95 | 0,98 | 1,01 | 1,04 | 1,16 | 1,31 | 1,56 | 1,99 | 2,40 | 2,45 | — | — |
| 440 | 0,90 | 0,92 | 0,94 | 0,97 | 1,00 | 1,02 | 1,12 | 1,24 | 1,43 | 1,75 | 1,98 | 2,38 | — | — |
| 450 | 0,90 | 0,92 | 0,94 | 0,96 | 0,99 | 1,01 | 1,08 | 1,19 | 1,34 | 1,56 | 1,75 | 1,99 | — | — |
| 460 | 0,90 | 0,92 | 0,93 | 0,95 | 0,98 | 1,00 | 1,06 | 1,15 | 1,27 | 1,44 | 1,60 | 1,75 | — | — |
| 470 | 0,90 | 0,91 | 0,93 | 0,95 | 0,97 | 0,99 | 1,04 | 1,11 | 1,20 | 1,34 | 1,47 | 1,59 | — | — |
| 480 | 0,90 | 0,91 | 0,93 | 0,94 | 0,96 | 0,98 | 1,02 | 1,08 | 1,16 | 1,26 | 1,37 | 1,46 | — | — |
| 490 | 0,90 | 0,91 | 0,93 | 0,94 | 0,95 | 0,97 | 1,01 | 1,06 | 1,12 | 1,20 | 1,29 | 1,36 | — | — |
| 500 | 0,90 | 0,91 | 0,92 | 0,94 | 0,95 | 0,96 | 1,00 | 1,04 | 1,09 | 1,15 | 1,22 | 1,29 | — | — |
| 510 | 0,89 | 0,91 | 0,92 | 0,93 | 0,94 | 0,95 | 0,99 | 1,02 | 1,06 | 1,11 | — | — | — | — |
| 520 | 0,89 | 0,91 | 0,92 | 0,93 | 0,94 | 0,95 | 0,98 | 1,01 | 1,04 | 1,09 | — | — | — | — |
| 530 | 0,89 | 0,91 | 0,92 | 0,93 | 0,94 | 0,95 | 0,97 | 1,00 | 1,02 | 1,07 | — | — | — | — |
| 540 | 0,89 | 0,91 | 0,92 | 0,93 | 0,93 | 0,94 | 0,96 | 0,98 | 1,01 | 1,04 | — | — | — | — |
| 550 | 0,89 | 0,91 | 0,92 | 0,92 | 0,93 | 0,94 | 0,95 | 0,97 | 0,99 | 1,02 | 1,04 | 1,06 | — | — |
| 560 | 0,89 | 0,91 | 0,91 | 0,92 | 0,93 | 0,93 | 0,95 | 0,96 | 0,98 | 1,00 | — | — | — | — |
| 570 | 0,89 | 0,91 | 0,91 | 0,92 | 0,92 | 0,93 | 0,94 | 0,95 | 0,97 | 0,99 | — | — | — | — |
| 580 | 0,89 | 0,90 | 0,91 | 0,92 | 0,92 | 0,93 | 0,94 | 0,94 | 0,96 | 0,98 | — | — | — | — |
| 590 | 0,89 | 0,90 | 0,91 | 0,92 | 0,92 | 0,92 | 0,93 | 0,94 | 0,95 | 0,97 | — | — | — | — |
| 600 | 0,89 | 0,90 | 0,91 | 0,91 | 0,91 | 0,92 | 0,92 | 0,93 | 0,94 | 0,96 | 0,98 | 1,00 | — | — |
| 650 | 0,90 | 0,91 | 0,92 | 0,92 | 0,93 | 0,93 | 0,94 | 0,95 | 0,96 | 0,99 | 1,02 | 1,04 | — | — |
| 700 | 0,91 | 0,92 | 0,93 | 0,93 | 0,94 | 0,94 | 0,95 | 0,96 | 0,98 | 1,01 | 1,03 | 1,05 | — | — |

Key: (1). kg/cm². (2). Water. (3). Steam. (4). in saturation curve.

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Table 3-6. Physical characteristics of gaseous fuels.

| (1) Наименование газообразных топлив / (2) Температура, °C | (3) Коэффициент теплопроводности $\lambda\cdot10^3$, *ккал/м час град* | | | | | | | | | | | (4) Коэффициент кинема | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 | 900 | 1 000 | 0 | 100 | 200 | 300 |
| (6) I. Газ доменных печей | | | | | | | | | | | | | | | |
| (7) Коксовых | 2,13 | 2,77 | 3,39 | 3,99 | 4,57 | 5,14 | 5,70 | 6,25 | 6,79 | 7,32 | 7,84 | 12,7 | 21,7 | 32,9 | 45,8 |
| (8) II Генераторный газ | | | | | | | | | | | | | | | |
| (9) *А. Из кускового топлива* | | | | | | | | | | | | | | | |
| (10) Подмосковный уголь[1] | 2,88 | 3,74 | 4,57 | 5,38 | 6,16 | 6,92 | 7,67 | 8,41 | 9,14 | 9,85 | 10,5 | 14,4 | 24,6 | 37,1 | 51,6 |
| (11) *Б. Из мелкозернистого топлива (0÷6 мм) (газификация во взвешенном слое)* | | | | | | | | | | | | | | | |
| (12) Фрезерный торф | 2,66 | 3,46 | 4,24 | 4,99 | 5,72 | 6,44 | 7,14 | 7,83 | 8,52 | 9,20 | 9,87 | 14,1 | 24,2 | 36,6 | 51,1 |
| (13) Подмосковный уголь | 2,40 | 3,12 | 3,81 | 4,47 | 5,11 | 5,74 | 6,36 | 6,96 | 7,55 | 8,13 | 8,70 | 13,4 | 22,8 | 34,4 | 47,8 |
| (14) III. Газ подземной газификации | | | | | | | | | | | | | | | |
| (15) Из каменного угля | 2,67 | 3,47 | 4,26 | 5,02 | 5,74 | 6,45 | 7,15 | 7,84 | 8,52 | 9,19 | 9,86 | 13,7 | 23,6 | 35,5 | 49,2 |
| (16) Из подмосковного угля | 2,89 | 3,76 | 4,59 | 5,40 | 6,19 | 6,97 | 7,74 | 8,51 | 9,22 | 9,93 | 10,6 | 14,3 | 24,5 | 36,9 | 51,1 |
| (17) IV. Газ коксовых печей | | | | | | | | | | | | | | | |
| (18) Очищенный | 6,85 | 8,95 | 11,0 | 12,9 | 14,8 | 16,7 | 18,6 | 20,4 | 22,2 | 24,0 | 25,7 | 25,9 | 44,2 | 66,7 | 92,9 |
| (19) Неочищенный | 6,83 | 8,93 | 10,9 | 12,8 | 14,7 | 16,6 | 18,5 | 20,3 | 22,1 | 23,9 | 25,6 | 24,6 | 41,6 | 64,1 | 89,2 |
| (20) V. Природный газ чисто газовых месторождений | | | | | | | | | | | | | | | |
| (21) Бугурусланский | 2,38 | 3,43 | 4,52 | 5,67 | 6,84 | 8,05 | 9,29 | 10,6 | 11,9 | 13,2 | 14,5 | 12,2 | 21,1 | 32,3 | 45,0 |
| (22) Елшанский (Саратовский)[2] | 2,51 | 3,62 | 4,77 | 5,98 | 7,21 | 8,49 | 9,79 | 11,1 | 12,4 | 13,8 | 15,2 | 13,6 | 23,5 | 36,0 | 50,2 |
| (23) Дашавский (Западная Украина)[3] | 2,51 | 3,62 | 4,77 | 5,98 | 7,21 | 8,49 | 9,79 | 11,1 | 12,4 | 13,8 | 15,2 | 14,3 | 24,6 | 37,7 | 52,6 |

| тической вязкости $\nu \cdot 10^6$, $м^2/сек$ | | | | | | | (5) Критерий физических свойств $Pr$ | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 400 | 500 | 600 | 700 | 800 | 900 | 1 000 | 0 | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 | 900 | 1 000 |
| 60,0 | 76,7 | 94,2 | 113 | 135 | 157 | 181 | 0,682 | 0,672 | 0,668 | 0,665 | 0,668 | 0,673 | 0,678 | 0,682 | 0,686 | 0,690 | 0,693 |
| 68,0 | 86,4 | 106 | 128 | 151 | 176 | 203 | 0,539 | 0,528 | 0,525 | 0,524 | 0,529 | 0,534 | 0,539 | 0,542 | 0,545 | 0,548 | 0,551 |
| 67,5 | 85,8 | 106 | 128 | 152 | 177 | 204 | 0,608 | 0,603 | 0,600 | 0,601 | 0,608 | 0,616 | [illegible] | 0,628 | 0,632 | 0,636 | 0,638 |
| 63,0 | 80,0 | 98,4 | 118 | 140 | 164 | 188 | 0,630 | 0,619 | 0,614 | 0,615 | 0,621 | 0,626 | 0,630 | 0,636 | 0,640 | 0,645 | 0,649 |
| 64,8 | 82,5 | 102 | 122 | 145 | 168 | 196 | 0,590 | 0,583 | 0,576 | 0,573 | 0,579 | 0,585 | 0,589 | 0,593 | 0,595 | 0,600 | 0,604 |
| 67,5 | 85,5 | 105 | 127 | 151 | 175 | 204 | 0,565 | 0,555 | 0,550 | [illegible] | 0,553 | 0,555 | 0,557 | 0,560 | 0,564 | 0,568 | 0,573 |
| 122 | 156 | 193 | 233 | 273 | 319 | 368 | 0,425 | 0,430 | 0,440 | 0,454 | 0,465 | 0,475 | 0,483 | 0,493 | 0,500 | [illegible] | 0,514 |
| 117 | 149 | 185 | 223 | 264 | 307 | 353 | 0,420 | 0,429 | 0,440 | 0,455 | 0,467 | 0,477 | 0,486 | 0,495 | 0,503 | 0,510 | 0,517 |
| 60,2 | 77,0 | 95,7 | 117 | 138 | 161 | 186 | 0,709 | 0,708 | 0,738 | 0,768 | 0,792 | 0,816 | 0,832 | 0,842 | 0,849 | 0,856 | 0,863 |
| 67,0 | 85,9 | 107 | 130 | 154 | 180 | 207 | 0,735 | 0,734 | 0,763 | 0,797 | 0,836 | 0,862 | 0,886 | 0,904 | 0,917 | 0,925 | 0,928 |
| 70,3 | 90,0 | 112 | 136 | 161 | 188 | 217 | 0,735 | 0,734 | 0,763 | 0,797 | 0,836 | 0,862 | 0,886 | 0,904 | 0,917 | 0,925 | 0,928 |

Key: (1). Designation of gaseous fuels. (2). Temperature. (3). Coefficient of thermal conductivity $\lambda \cdot 10^2$, kcal/m h deg. (4). Coefficient of kinematic viscosity/ductility/toughness m²/s. (5). Criterion of physical properties Pr. (6). Gas of blast furnaces. (7). Coke. (8). Generator gas. (9). From cake fuel/propellant. (10). Moscow carbon/coal[1].

FOOTNOTE [1]. The characteristics of generator gas from Moscow carbon/coal apply to all generator gases from the cake fuel/propellant and gases of underground gasification (RN 2-C2). ENDFOOTNOTE.

(11). B. From fine-grained fuel/propellant (C-6 mm) (gasification in suspended bed). (12). Milling peat. (13). Moscow carbon/coal. (14). Gas of subterranean gasification. (15). From coal. (16). From Moscow carbon/coal. (17). Gas of coke ovens. (18). Purified. (19). Not refined. (20). Natural gas of purely gas fields. (21). Buguruslansk. (22). Yelshansk (Saratov)[2].

FOOTNOTE [2]. The characteristics of Yelshansk natural gas apply to Ukhtinsk and Kurdyumsk gases. ENDFOOTNOTE.

(23). Dashavsk (Western Ukraine)[3].

FOOTNOTE [3]. The characteristics of Dashavsk natural gas apply to Melitopol' gas. ENDFOOTNOTE.

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# Chapter Four.

## VOLUMES AND ENTHALPY OF AIR AND COMBUSTION PRODUCTS.

### 4-A. Calculation of volumes and enthalpy.

4-01. All calculations of volumes and enthalpy of air and products of combustion are conducted on 1 kg of solid or liquid propellant or on 1 $nm^3$ of dry gaseous fuel. With the drying of fuel/propellant according to the extended cycle the calculations are conducted on 1 kg of the dried slightly fuel/propellant.

Mechanical incomplete burning is considered by introduction to the calculations of the conditional fuel consumption:

$$B_p = \frac{100 - q_4}{100} B \text{ kg/h}.$$

All formulas relate to the case of the complete combustion of fuel/propellant, but by sufficient for the calculations precision/accuracy are applied with the insignificant chemical incompleteness combustion, which corresponds to the indicated in the

norms values of losses $q_3$.

In all formulas the volume of gases is expressed in the normal cubic meters ($nm^3$), the composition of solid and liquid propellants - in the percentages by the weight, and vapor - by the volume.

During the computation of volumes volume 1 mole for all gases was received equal to 22.41 $nm^3$ (as for the perfect gas). In this case into the computation of enthalpy the error from the difference in the volumes of the moles of real and perfect gases is not introduced, since heat capacity of gases are related to the same volume of mole (s. p. 3-01).

4-02. Volumes and weights of air and combustion products during combustion of solid and liquid propellants are determined from given below formulas.

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Theoretical quantity of dry air, necessary for the complete combustion of fuel/propellant,

$$V^0 = 0{,}0889\,(C^p + 0{,}375 S^p_{op+\kappa}) + 0{,}265 H^p - 0{,}0333 O^p \text{ нм}^3/\text{кг}; \quad (1) \quad (4\text{-}02)$$

$$L^0 = 0{,}115\,(C^p + 0{,}375 S^p_{op+\kappa}) + 0{,}342 H^p - 0{,}0431 O^p \text{ кг/кг}. \quad (2) \quad (4\text{-}03)$$

Key: (1). nm³/kg. (2). kg/kg.

The minimum volumes of combustion products which would be obtained with the complete combustion of fuel/propellant with the theoretically necessary quantity of air ($\alpha$=1):

Theoretical volume of nitrogen

$$V^0_{N_2} = 0{,}79 V^0 + 0{,}8\,\frac{N^p}{100} \text{ нм}^3/\text{кг}. \quad (1) \quad (4\text{-}04)$$

Key: (1). nm²/kg.

Volume of the triatomic gases

$$V_{RO_2} = 1{,}866\,\frac{C^p + 0{,}375 S^p_{op+\kappa}}{100} \text{ нм}^3/\text{кг}. \quad (1) \quad (4\text{-}05)$$

Key: (1). nm³/kg.

Theoretical volume of the water vapors

$$V^0_{H_2O} = 0{,}111H^p + 0{,}0124W^p + 0{,}0161V^0 \text{ нм}^3/\text{кг}.^{(1)} \quad (4\text{-}06)$$

Key: (1). nm³/kg.

During steam blasting or steam pulverization of petroleum residue with the expenditure/consumption of steam $G_\phi$ kg/kg in value $V^0_{H_2O}$ is included term $1{,}24G_\phi$.

With the excess air $\alpha$>1 the calculation is conducted according to the following formulas:

volume of the water vapors

$$V_{H_2O} = V^0_{H_2O} + 0{,}0161(\alpha - 1)V^0 \text{ нм}^3/\text{кг}.^{(1)} \quad (4\text{-}07)$$

Key: (1). nm³/kg.

Volume of the flue gases

$$V_г = V_{RO_2} + V^0_{N_2} + V_{H_2O} + (\alpha - 1)V^0 \text{ нм}^3/\text{кг}.^{(1)} \quad (4\text{-}08)$$

Key: (1). nm³/kg.

The volume fractions of triatomic gases, equal to the partial gas pressures at the total pressure 1 ats(abs.):

$$r_{RO_2} = \frac{V_{RO_2}}{V_z}; \qquad (4\text{-}09)$$

$$r_{H_2O} = \frac{V_{H_2O}}{V_z}. \qquad (4\text{-}10)$$

Ash concentration in the flue gases

$$\mu = \frac{10A^p a_{ун}}{V_z} \text{ г/нм}^3. \ (1) \qquad (4\text{-}11)$$

Key: (1). g/nm³.

where $a_{ун}$ - share of the ash of fuel/propellant, taken away by the gases; it is determined on p. 4-07.

Weight of the flue gases

$$G_z = 1 - \frac{A^p}{100} + 1{,}306\alpha V^0 \text{ кг/кг.} \ (1) \qquad (4\text{-}12)$$

Key: (1). kg/kg.

During steam blasting or steam pulverization of petroleum residue in value $G_z$ is included term $G_ф$.

The special features/peculiarities of calculation during the combustion of schists are shown in p. 4-11.

4-03. Volumes and weights of air and combustion products during combustion 1 nm³ of dry gaseous fuel are determined from following formulas:

Theoretical quantity of air

$$V^0 = 0{,}0476\,[0{,}5\,CO + 0{,}5\,H_2 + 1{,}5\,H_2S + \Sigma\left(m + \frac{n}{4}\right) C_mH_n{}^{*} - O_2]\ \text{нм}^3/\text{нм}^3 \ (1) \quad (4\text{-}13)$$

Key: (1). nm³/nm³.

Theoretical volume of nitrogen

$$V^0_{N_2} = 0{,}79V^0 + \frac{N_2}{100}\ \text{нм}^3/\text{нм}^3 \ (1) \quad (4\text{-}14)$$

Key: (1). nm³/nm³.

Volume of the triatomic gases

$$V_{RO_2} = 0{,}01\,[CO_2 + CO + H_2S + \Sigma m C_mH_n{}^{*}]\ \text{нм}^3/\text{нм}^3 \ (1) \quad (4\text{-}15)$$

Key: (1). nm³/nm³.

Theoretical volume of the water vapors

$$V^0_{H_2O} = 0{,}01\left[H_2S + H_2 + \Sigma \frac{n}{2} C_mH_n{}^{*} + 0{,}124 d_{г.тл.}\right] + 0{,}0161V^0\ \text{нм}^3/\text{нм}^3 \ (1) \quad (4\text{-}16)$$

FOOTNOTE [1] : With the content in the fuel of a small quantity (up to 3%) of umlimiting hydro-carbons of unknown composition, they are assumed to consist of $C_2H_4$. END FOOTNOTE.

Key: (1). $nm^3/nm^3$.

$d_{г.тл}$ - the moisture content of gaseous fuel, in reference to 1 $nm^3$ of dry gas, $g/nm^3$.

Volumes and volume fractions of gases with the excess air $\alpha>1$ are determined from formulas (4-07)-(4-10) inclusively.

The specific gravity/weight of the dry gas

$$\gamma^c_{г.тл} = 0{,}01\,[1{,}96\,CO_2 + 1{,}52\,H_2S + 1{,}25\,N_2 + 1{,}43O_2 + 1{,}25\,CO + 0{,}0899H_2 + \Sigma\,(0{,}536m + 0{,}045n)\,C_mH_n{}^*]\,кг/нм^3.^{(1)} \quad (4\text{-}17)$$

Key: (1). $kg/nm^3$.

Weight of the flue gases

$$G_г = \gamma^c_{г.тл} + \frac{d_{г.тл}}{1\,000} + 1{,}306\alpha V^0\ кг/нм^3.^{(1)} \quad (4\text{-}18)$$

Key: (1). $kg/nm^3$.

4-04. In formulas for determining volume of water vapors (4-06), (4-07) and (4-16) moisture content of air d is accepted by equal, 10 g by 1 kg of dry air. If by assignment the moisture content of air differs significantly from that indicated, then the volume of water vapors, determined according to these formulas, must be changed by

$$\Delta V_{H_2O} = 0{,}0016\alpha V^0 (d - 10)\ \text{нм}^3/\text{кг}\ \overset{(1)}{\text{или}}\ \text{нм}^3/\text{нм}^3. \quad (4\text{-}19)$$

Key: (1). nm³/kg or nm³/nm³.

and the weight of flue gases to

$$\Delta G_z = 0{,}0013\alpha V^0 (d - 10)\ \text{кг}/\text{кг}\ \overset{(1)}{\text{или}}\ \text{кг}/\text{нм}^3 \quad (4\text{-}20)$$

Key: (1). kg/kg or kg/nm³.

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4-05. Special features/peculiarities of calculation of volumes during recirculation are shown in p. 4-10.

4-06. Enthalpy of flue gases on 1 kg or on 1 nm³ of burned fuel/propellant is calculated according to tc formula

$$I = I_z^0 + (\alpha - 1)\, I_в^0\ \text{ккал}/\text{кг}\ \overset{(1)}{\text{или}}\ \text{ккал}/\text{нм}^3. \quad (4\text{-}21)$$

by Key: (1). kcal/kg or kcal/nm³.

Enthalpy of gases at excess air ratio $\alpha$=1 and temperature of gases of $\theta$°C

$$I_z^0 = V_{R_2O}\,(c\theta)_{CO_2} + V_{N_2}^0\,(c\theta)_{N_2} + V_{H_2O}^0\,(c\theta)_{H_2O}\ \text{ккал}/\text{кг}\ \overset{(1)}{\text{или}}\ \text{ккал}/\text{нм}^3 \quad (4\text{-}22)$$

Key: (1). kcal/kg or kcal/nm³.

Enthalpy of the theoretically necessary quantity of air at temperature of θ°C

$$I_{в}^{0} = V^{0}\,(c\theta)_{в}\ \overset{(1)}{ккал/кг}\ или\ ккал/нм^{3}. \qquad (4\text{-}23)$$

Key: (1). kcal/kg or kcal/nm³.

The volumes of the theoretically necessary quantities of the dry air $V^{0}$ and gases $V_{RO_2}$, $V_{N_2}^{0}$ and $V_{H_2O}^{0}$ are determined from formulas p. 4-02 for solid and liquid propellants and p. 4-03 for the gaseous fuel.

The enthalpy 1 nm³ of humid air $(c\theta)_{в}$, carbonic acid $(c\theta)_{CO_2}$, nitrogen $(c\theta)_{N_2}$ and water vapors $(c\theta)_{H_2O}$ are determined on PN 4-04.

4-07. If given value of escape of ash from heating

$$1\,000\,\frac{a_{ун} A^{р}}{Q_{н}^{р}} > 6,$$

then to enthalpy of flue gases should be added thermal content of ash, determined according to tc formula

$$I_{зл} = (c\theta)_{зл}\,\frac{A_{р}}{100}\,a_{ун}\ \overset{(1)}{ккал/кг}. \qquad (4\text{-}24)$$

Key: (1). kcal/kg.

where $(c\vartheta)_{з.л}$ - enthalpy 1 kg of ash, determined cn RN 4-04, kcal/kg;

$a_{ун}$ - share of the ash of fuel/prcpellant, taken away by the gases; it takes as the equal to:

for the pulverized-coal combustors with the dry slag removal - 0.9;

for shaft-mill heatings (besides the case of combusting the schists) - 0.85; during the ccmtustion of schists - 0.7;

for the liquid-tath furnaces - on RN 5-05;

for the heatings with the heated slag funnels - 0.8-0.85;

for the layer heatings - on RN 5-03 and 5-04.

In the presence of the built-in ash catchers should be considered the decrease of the ash contents in the flue gases for the arranged/located after the ash catcher heating surfaces. The efficiencies of the built-in ash catchers for these calculaticns take as the equal to 40o/o fcr louvered ash catchers and 75o/c for

multicyclone dust collectors.

4-08. For standard fuels/propellants whose characteristics are given in BN 2-01 and 2-02, are calculated and represented in BN 4-02 and 4-03 volumes, also, in BN 4-05 enthalpy of air and flue gases with excess air ratio $\alpha$=1.

4-09. Calculation of volumes and enthalpy is recommended to conduct in the form of tables, represented in BN 4-01.

During computation table one should for each value of the excess air ratio $\alpha$ determine value I only in the limits, a little which exceed the actually possible limits of the temperatures in gas conduits. About values I it is expedient to place value $\Delta$I of differences in two adjacent in the vertical line values I with one $\alpha$. With the help of these differences are determined in the process of calculation intermediate values I and $\theta$.

4-10. Recirculation of gases in calculations of volume and enthalpy of combustion products with return of gases into flue, arranged/located to place of selection of these gasses, is considered on entire channel from place of introduction/input of recirculating gases to place of their selection.

Coefficient of the recirculation

$$r = \frac{V_{рц}}{V_{г.отб}}, \quad (4\text{-}25)$$

where $V_{рц}$ and $V_{г.отб}$ - volumes of gases on 1 kg of fuel/propellant, selected/taken for the recirculation, and in section/cut of selection without the account to recirculation, nm³/kg.

Volume of gases at any point of channel from the place of return to the place of the selection

$$V_{г.рц} = V_г + rV_{г.отб} \text{ нм}^3/\text{кг}^{(1)}, \quad (4\text{-}26)$$

Key: (1). nm³/kg.

where $V_г$ - volume of gases at the particular point without the account to recirculation, nm³/kg.

Enthalpy of gases in the place of the return of the recirculating gases after the mixing

$$I_{г.рц} = I_г + rI_{г.отб} \text{ ккал/кг}^{(1)}. \quad (4\text{-}27)$$

Key: (1). kcal/kg.

The temperature of gases after the mixing

$$\vartheta_{г.рц} = \frac{I_{г.рц}}{(Vc)_{г.рц}} \text{ °C}, \quad (4\text{-}28)$$

where the total heat capacity of the products of the combustion 1 kg of fuel/propellant after mixing is determined frcm to the formula

$$(Vc)_{г.рц} = (Vc)_г + r\,(Vc)_{г.отб}\ \text{ккал/кг град}^{(1)}, \quad (4\text{-}29)$$

Key: (1). kcal/kg deg.

where $I_г$ and $(Vc)_г$ - enthalpy and total heat capacity in the place of the return before the mixing, kcal/kg and kcal/kg deg; $I_{г.отб}$ and $(Vc)_{г.отб}$ - the same for the gases, which remain after the place of selection.

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In further sections of channel to the place of selection the temperature of gases is calculated with the help of the total heat capacity, determined acccrding to formula (4.29), where $(Vc)_г$ and $(Vc)_{г.отб}$ are accepted according to the temperature in the designed section/cut of flue.

With the gas bleed from the heating for the drying of fuel/propellant and the return cf the prcducts of drying into the heating the computation of vclumes and enthalpy is produced without the account to recirculation.

4-11. During combustion of schists volumes and weight of combustion products are calculated with corrections for decomposition/expansion of carbonates.

In RN 2-01 are given ash content of schists to working mass $A^p\%$. and carbonic acid of carbonates $(CO_2)^p_k\%$.

With combustion of schists the carbonates partially or completely are decomposed/expanded and separating carbonic acid increases the volume of triatomic gases. Separated part by weight of carbonic acid is called the coefficient of the expansion of carbonates k. It is accepted

during the layer combustion k=0.7;

during the chamber combustion k=1.0.

The calculated ash contents in the fuel/propellant taking into account the undecomposed carbonates is approximately equal to:

$$A_k^p = A^p + (1 - k)(CO_2)^p_k\%. \quad (4\text{-}30)$$

Volume of carbonic acid

$$V_{RO_2,к} = V_{RO_2} + 0{,}509\frac{(CO_2)^р_к}{100}k \text{ нм}^3/кг. \quad (4\text{-}31)$$

Key: (1). nm³/kg.

Volume of the gases

$$V_{г,к} = V_г + 0{,}509\frac{(CO_2)^р_к}{100}k \text{ нм}^3/кг. \quad (4\text{-}32)$$

Key: (1). nm²/kg.

Weight of the gases

$$G_{г,к} = G_г + \frac{(CO_2)^р_к}{100}k \text{ кг/кг}. \quad (4\text{-}33)$$

Key: (1) kg/kg.

The volume fracticns of the triatomic gases

$$r_{RO_2,к} = \frac{V_{RO_2,к}}{V_{г,к}};\ r_{H_2O,к} = \frac{V_{H_2O}}{V_{г,к}}.$$

4-12. During combustion cf mixture cf fuels/propellants calculation of volumes and enthalpy of combustion products is recommended to conduct fcr each fuel/propellant separately on 1 kg of solid or liquid propellant and 1 nm³ of dry gas.

By obtained for each fuel/propellant values $V_в$, $V_г$ and I are

determined the volumes and the enthalpy cf the combustion products of the mixture:

a) for the mixture cf two uniform fuels/propellants (solid, liquid or vapor) - according to the formulas cf the mixing:

$$V^0 = g'V^{0\prime} + (1-g')V^{0\prime\prime} \quad \text{нм}^3/\text{кг}^{(1)} \text{ и т.п. } \text{нм}^3/\text{нм}^3 \qquad (4\text{-}34)$$

Key: (1). nm³/kg or nm³/nm³

and so forth;

b) for the mixture cf solid or liquid propellant with vapor

$$V^0 = V^{0\prime} + \quad \text{нм}^3/\text{кг} \text{ и т. д.}^{(1)} \qquad (4\text{-}35)$$

Key: (1). nm³/kg, etc.

Respectively entire further calculation is conducted on 1 kg of solid or liquid propellant.

The volume fracticns of triatomic gases $r_{RO_2}$ and $r_{H_2O}$ for the mixture of fuels/propellants are calculated according to the formulas:

a) for the mixture cf two uniform fuels/propellants

$$r_{RO_2} = \frac{g'V'_{RO_2} + (1-g')V''_{RO_2}}{V_z} \quad (4\text{-}36)$$

and analogous with this is determined $r_{H_2O}$;

b) for the mixture of solid or liquid propellant with the vapor

$$r_{RO_2} = \frac{V'_{RO_2} + xV''_{RO_2}}{V_z} \quad (4\text{-}37)$$

and respectively is determined $r_{H_2O}$.

The specific gravity/weight of the products of combustion for the mixture of fuels/propellants is calculated according to the formulas:

a) for the mixture of the uniform fuels/propellants

$$\gamma = \frac{g'\gamma'V'_z + (1-g')\gamma''V''_z}{V_z} \; \text{кг/нм}^3; \quad (4\text{-}38)$$

Key: (1). kg/nm³.

b) for the mixture of solid or liquid propellant with vapor

$$\gamma = \frac{\gamma'V'_z + x\gamma''V''_z}{V_z} \; \text{кг/нм}^3. \quad (4\text{-}39)$$

Key: (1). kg/nm³.

In formulas (4-34), (4.36) and (4.38) the designations with the prime relate to the first fuel/propellant, and with two primes - to the second; in formulas (4-35), (4-37) and (4-39) the designations with the prime relate to the solid (or liquid) propellant, with two primes - to the vapor.

In formulas (4-34), (4-36) and (4-38) g' - part by weight of the first fuel/propellant in the mixture kg/kg, while in formulas (4-35), (4-37) and (4-39) x - a quantity of normal cubic meters of gas falling in the mixture on 1 kg of solid (or liquid) propellant. If the mixture of fuels/propellants is prescribed/assigned not by weight or volume fractions, but in the shares of the heat release of each fuel/propellant q' and (1-q'), their corresponding weight or volume fractions are defined, as noted above, according to formula (2-11) or (2-13).

4-B. Excess air ratio and suctions in the boiler aggregate/unit.

4-13. Excess air ratio in heating, which corresponds to composition of gases at the end of heating, is accepted on RN 5-02-5-05 in depending on type of combustion system and kind of burned fuel/propellant.

. 'e Value of excess air ratio in separate sections/cuts of gas

circuit of boiler aggregate/unit is determined by method of addition of excess air ratio in heating with suctions in flues, arranged/located between heating and section/cut in question.

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4-15. Values of suctions of air in separate elements of boiler installation should be taken on SN 4-06.

During the use/application of the more advanced constructions/designs of the enclosures/protections of the flues, for which experimentally is confirmed the decrease of the value of suction, calculation is conducted according to the reduced values.

4-16. During determination of air flow rate through air preheater are considered suctions in heating and system of pulverized coal preparation.

A quantity of air at the output from the air preheater, referred to theoretically necessary, is determined from the formula

$$\beta''_{en} = \alpha_m - \Delta\alpha_m - \Delta\alpha_{n.e.y}; \quad (4\text{-}40a)$$

at the entrance (in the absence of recirculation)

at the entrance (in the absence of recirculation)

$$\beta'_{вп} = \beta''_{вп} + \Delta\alpha_{вп}, \quad (4\text{-}41)$$

where $\Delta\alpha_{т}$ - suction in the furnace chamber/camera; it is accepted on RN4-06;

$\Delta\alpha_{пл.у}$ - suction in the system of pulverized coal preparation, determined according to the data of the calculation of dust-preparatory installation in accordance with p. 4-17, and in the absence of this calculation - on the average data, given of RN 4-07;

$\Delta\alpha_{вп}$ - overflow of air from the air side into the gas, taken to the equal to the suction of air in the air preheater.

For the layer and mazut heatings

$$\beta''_{вп} = \alpha_{т} - \Delta\alpha_{т}. \quad (4\text{-}40б)$$

4.17. For calculating quantity of air, passing through air preheater, during determination $\beta''_{вп}$ is considered suction in closed systems of pulverized coal preparation; suction in extended dust-systems is not considered.

In the calculations of dust-preparatory installation the value of suction $k_{np}$ is expressed in the fractions of a quantity of the drying agent. For obtaining by that utilized in the thermal design of the boiler aggregate/unit of the value of suction, expressed in the fractions/portions of the theoretically necessary quantity of air, $\Delta a_{n.s.y}$. the value of suction $k_{np}$ is counted over according to the formula

$$\Delta a_{n.s.y} = k_{np} \frac{g_1}{L^0}, \qquad (4\text{-}42)$$

where $g_1$ - a quantity of the drying agent on 1 kg of damp/crude fuel/propellant, kg/kg;

$L_0$ - weight theoretically necessary for the combustion quantity of air, kg/kg.

In the case of the additive of cold air in the dust-preparatory installation the value of additive conditionally is included in the value of suction $\Delta a_{n.s.y}$.

4-18. With changes of coefficient of evaporation of aggregate/unit within limits of 100-75o/o nominal ones excess air ratio in heating must be supported by constant, equal to value, indicated in RN 5-02-5-C5.

With the coefficient of evaporation of aggregate/unit D less than 75o/o nominal, the excess air ratio in the heating can be determined from the approximate equality

$$\alpha_m^D = \alpha_m + \left(0{,}75 - \frac{D}{D_{ном}}\right). \quad (4\text{-}43)$$

where $\alpha_m$ - excess air ratio with the nominal load.

In those combustion systems where flow of the bulk of air is determined not only by the conditions for combustion, but also by the conditions of the transport of fuel/propellant (heating of Shershnev, shaft- mill heatings, etc.), excess air in the heating with the lowered/reduced coefficient of evaporation should be selected taking into account this fact.

The values of suctions in the convective flues with all loads of aggregate/unit are received as constant/invariable ones.

Chapter Five

HEAT BALANCE OF BOILER AGGREGATE/UNIT.

5-01. Composition of heat balance of boiler aggregate/unit consists in establishment of equality between acted into aggregate/unit quantity of heat, called available heat $Q_p^p$ and sum of usefully absorbed heat $Q_1$ and heat losses $Q_2$, $Q_3$, $Q_4$, $Q_5$ and $Q_6$. On the basis of heat balance are calculated the efficiency and the necessary fuel consumption.

Heat balance is comprised in connection with the steady thermal condition of boiler aggregate/unit on 1 kg of solid ones and liquid and 1 nm³ of gaseous fuels.

General/common/total equation of the heat balance:

$$Q_p^p = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6 \text{ ккал/кг}^{(1)} \text{ или ккал/нм}^3. \qquad (5\text{-}01)$$

Key: (1). kcal/kg or kcal/nm³.

5-02. Available heat on 1 kg of solid or liquid or on 1 nm³ gaseous fuel $Q_p^p$ is determined from formulas:

$$\left.\begin{aligned} Q_p^p &= Q_n^p + Q_{e.вн ш} + i_{тл} + Q_{ф} - Q_к \ (1)\ ккал/кг; \\ Q_p^p &= Q_n^c + Q_{e.вн ш} + i_{тл} + Q_{ф} \ (2)\ ккал/нм^3, \end{aligned}\right\} \quad (5\text{-}02)$$

Key: (1). kcal/kg. (2). kcal/nm³.

where $Q_n^p$ and $Q_n^c$ - lowest heat of combustions cf working mass solid and liquid and the dry mass of gaseous fuels, kcal/kg or kcal/nm³.

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5-03. Heat, introduced with entering bciler aggregate/unit air, during preheating of latter out of aggregate/unit by choice vapor, by waste heat and the like is determined frcm tc formula

$$Q_{e.вн ш} = \beta' [(I_e^0)' - I_{х.е}^0] \ ккал/кг \ (1) \ или \ ккал/нм^3, \quad (5\text{-}03)$$

Key: (1). kcal/kg or kcal/nm³.

where $\beta'$ - ratio of a quantity cf air at the entrance into the boiler aggregate/unit to theoretically necessary; $(I_e^0)'$ and $I_{х.е}^0$ - enthalpy of the theoretically necessary quantity of air at the entrance into the boiler aggregate/unit and the cold air; they are determined by an I$\vartheta$-table (RN 4-05), kcal/kg or kcal/nm³. The temperature of cold air in the absence of special indications takes as the equal to 30°C.

5-04. Physical heat of fuel/propellant $i_{m.}$ is designed from to formula

$$i_{m\text{л}} = c_{m\text{л}} t_{m\text{л}} \text{ ккал/кг} \overset{(1)}{\text{или}} \text{ ккал/нм}^3,$$

Key: (1). kcal/kg or kcal/nm³.

where $c_{m.}$ - heat capacity of propellant, determined, on RN 3-01, kcal/kg deg or kcal/nm³ deg; $t_{m.}$ - temperature of fuel/propellant, °C.

The physical heat of fuel/propellant is considered when it is preliminarily heated due to the extraneous source of heat (steam preheating of petroleum residue, steam desiccators, etc.), and also with the drying of fuel/propellant on the extended cycle when temperature and humidity of fuel/propellant should be accepted due to its state before the heating. In the absence of extraneous preheating physical heat is considered only for the fuels/propellants with the humidity

$$W^p > \frac{Q^p_н}{150}\ \%.$$

In this case the temperature of fuel/propellant is accepted

$t_{m.} = 20°$ C.

During the calculation of aggregate/unit with the dust-preparatory system, which works on the closed cycle, preheating fuel/propellant and its drying separately are not considered.

In those of the case when into the boiler aggregate/unit is supplied the congealing fuel/propellant (which must be specially stipulated in the assignment), from they are of a size the available heat it is subtracted the heat consumption, spent on the thawing out:

$$\Delta Q_{m.s} = 0{,}8\left(W^p - W^a\frac{100 - W^p}{100 - W^a}\right) \text{ккал/кг}, \quad (5\text{-}04)$$

Key: (1). kcal/kg.

where $W^p$ and $W^a$ - moisture content general/common/total to the working mass and in the air-dried fuel/propellant, o/o.

5-05. Heat, introduced into aggregate/unit with steam blasting ("injection" vapor), $Q_\phi$ is determined from to formula

$$Q_\phi = G_\phi (i_\phi - 600) \text{ ккал/кг}, \quad (5\text{-}05)$$

Key: (1). kcal/kg.

where $G_\phi$ and $i_\phi$ - expenditure/consumption and enthalpy is steam that proceeds with blasting or fuel atomization, kg/kg and kcal/kg.

Expenditure/consumption of steam is accepted on the indications p. 16 of appendix V.

5-06. Heat, spent on expansion of carbonates during combustion of schists, $Q_к$ is determined from to formula

$$Q_к = 9{,}70k\,(CO_2)^р_к \text{ ккал/кг.}^{(1)}$$

Key: (1). kcal/kg.

The coefficient of the expansion of carbonates k is accepted on p. 4-11.

5-07. Heat losses in boiler aggregate/unit it is accepted to express by relative percents:

$$q_i = \frac{Q_i}{Q^р_р}\cdot 100\%.$$

The heat loss with the stack gases is defined as the difference between the enthalpy of combustion products at the output from the latter/last surface of heating boiler aggregate/unit and the enthalpy of the cold air:

$$q_2 = \frac{Q_2}{Q^р_р}\cdot 100 = \frac{(I_{ух} - \alpha_{ух} I^0_{х.в})(100 - q_4)}{Q^р_р}\ \%, \quad (5\text{-}06)$$

$I_{ух}$ - enthalpy of stack gases at appropriate excess air $\alpha_{ух}$ and

temperature $\vartheta_{yx}$ kcal/kg or kcal/nm³; $I^0_{x.s}$ - enthalpy of the theoretically necessary quantity of air at temperature of cold air, determined in accordance with p. 5-03, kcal/kg or kcal/nm³, $q_4$ - a heat loss from the mechanical incompleteness of combustion, c/o, it is determined on p. 5-09.

During the installation of the built-in ash catcher to value $I_{yx}$ in formula (5-06) is added the member, who considers the additional heat loss, called by the removal/distance of ash at elevated temperatures:

$$\Delta I_{sy} = \frac{\eta_{sy}}{100} a_{yn} \frac{A^p}{100} [(c\vartheta)_{s.s} - (c\vartheta_{yx})_{s.s}] \quad \text{(1) ккал/кг,}$$

Key: (1). kcal/kg.

where $\eta_{sy}$ - efficiency of ash catcher, taken on p. 4-07, o/o.

5-08. Heat loss from chemical incompleteness of combustion $q_3 = \frac{Q_3}{Q^p_p} \cdot 100\%$ is determined by total heat of combustion of products of incomplete combustion, which remain in stack gases.

Value $q_3$ for different fuels/propellants and combustion systems is accepted on RN 5-02-5-05.

5-09. Heat loss from mechanical incompleteness of combustion

determines by incomplete burning of fuel/propellant in slags, failure/dip/trough and escape (with partial return of latter into heating is considered only escape, not recovered by devices for return).

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Value $q_4$ is designed from the formula

$$q_4 = \frac{Q_4}{Q_p^p}\cdot 100 = \frac{\left(a_{шл+пр}\frac{\Gamma_{шл+пр}}{100-\Gamma_{шл+пр}} + a_{ун}\frac{\Gamma_{ун}}{100-\Gamma_{ун}}\right)7\,800A^p}{Q_p^p}\ \%, \quad (5\text{-}07)$$

where $a_{шл+пр}$ and $a_{ун}$ - share of the ash of fuel/propellant in the slag and failure/dip/trough and escape; $\Gamma_{шл+пр}$ and $\Gamma_{ун}$ - content of fuels in the slag and failure/dip/trough and escape, o/o; $A^p$ - ash content to the working mass of fuel/propellant, o/o.

In RN 5-02 and 5-05 are given values $q_4$ for the chamber furnaces with the dry and liquid slag removal. In RN 5-03 and 5-04 are given values a and $\Gamma$ for the layer heatings and corresponding to them values $q_4$. For the normal conditions of planning it should be used tabular values of $q_4$. In the case of considerable deviation from the tabular ash content during the combustion in the layer heatings, and also in the presence of the reliable experimental data about values a and $\Gamma$ for the specific constructions/designs of layer and chamber

furnaces and prescribed/assigned fuels/propellants, $q_4$ is calculated from formula (5-07).

5-10. Heat loss frca external cooling $q_5$ for stationary boiler aggregates/units is accepted on curves RN5 01.

With the loads, which differ from nominal it is more than by 25o/o, value $q_5$ is counted over according tc the formula

$$q_5 = q_5^{nom} \frac{D_{nom}}{D} \%. \qquad (5\text{-}08)$$

The heat loss from the external cooling of the system of pulverized coal preparation is small; it is tc a considerable extent compensated by the arrival of the heat, which separates with the work of mills, and therefore it is nct considered.

The laying out of the heat loss from the external cooling on the separate flues virtually does not affect the results of calculation. The fractions of this loss, which fall tc the separate flues, for the simplification are received as the proportional to the quantities of heat, loosened by gases in apprcpriate flues. Therefore, losses from external cooling they are considered by introduction to formula for determining the heat, returned by gases of the heating surface, the coefficient of the retention/preservation/maintaining the heat $\varphi$, determined according to the formula

$$\varphi = 1 - \frac{q_5}{100}. \qquad (5\text{-}09)$$

5-11. Loss with physical heat of slags $q_{6\,шл}$ is introduced into calculation for all fuels/propellants during chamber combustion with liquid slag removal and layer combustion. During the chamber combustion with dry slag removal $q_{6\,шл}$ it is considered only when $A^p > \frac{Q^p_н}{100}$ %.

The heat loss is determined from the formula

$$q_{6\,шл} = \frac{Q_{6\,шл}}{Q^p_p} \cdot 100 = \frac{a_{шл}\,(ct)_{шл}\,A^p}{Q^p_p}\ \%. \qquad (5\text{-}10)$$

where $a_{шл} = 1 - a_{ун}$ for the chamber furnaces is determined on value $a_{ун}$ in conformity with the indications p. 4-07, and for the layer heatings it takes as the equal to values $a_{шл+пр}$, led in RN 5-03 and 5-04; $(ct)_{шл}$ - enthalpy of slags, determined on RN 4-04, kcal/kg.

The temperature of slags with the dry slag removal takes as the equal to 600°C, and with the liquid slag removal - the temperature of the fluid state of ash $t_3$ plus of 100°C.

During the layer combustion of schists instead of $A^p$ is substituted value $A^p - 0.3\,(CO_2)^p_к$ %. The content of carbonic acid of carbonates $(CO_2)^p_к$ is given in RN 2-01 by second term in graph/count $A^p$.

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During the chamber combustion of schists the correction into value $A^p$ for the content of carbonic acid of carbonates is not introduced.

5-12. Heat loss to cooling of not connected with circulation of boiler panels and beams/gullies $q_{6\,ox\Lambda}$ in the absence of special indications is determined from formula

$$q_{6\,ox\Lambda} = \frac{Q_{6\,ox\Lambda}}{Q_p^p} \cdot 100\%.$$

or approximately

$$q_{6\,ox\Lambda} \approx \frac{100 \cdot 10^3 H_{ox\Lambda}}{Q_{\kappa.a}} \cdot 100\%, \quad (5\text{-}11)$$

where $H_{ox\Lambda}$ - beam-receiving surface of beams/gullies and panels, m², for latter is allowed only lateral converted into heating surface; $Q_{\kappa.a}$ - full/total/complete quantity of heat, usefully returned in boiler aggregate/unit, kcal/h, it is determined on p. 5-14.

5-13. Total heat loss in boiler aggregate/unit

$$\Sigma q = q_2 + q_3 + q_4 + q_5 + q_{6\,ш\Lambda} + q_{6\,ox\Lambda}\%. \quad (5\text{-}12)$$

Efficiency of boiler aggregate/unit (gross weight)

$$\eta_{\kappa.a} = 100 - \Sigma q\%. \quad (5\text{-}13)$$

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5-14. General/common/total expression for full/total/complete quantity of heat, usefully returned in boiler aggregate/unit, takes form:

$$Q_{к.а} = D_{пе}(i_{п.п} - i_{п.в}) + D_{н.п}(i_{н.п} - i_{п.в}) + D_{пр}(i'_{кип} - i_{п.в}) + D_{вт.пе}(i''_{вт.пе} - i'_{вт.пе}) + Q_{отб} \text{ ккал/час}^{(1)}, \quad (5\text{-}14)$$

Key: (1). kcal/h

where $D_{пе}$ kg/h - a quantity of manufactured superheated steam (during the consumption/production/generation only of superheated steam, that most frequently it is encountered, $D_{пе}$ equal to the coefficient of evaporation of aggregate/unit D) the enthalpy of superheated steam $i_{п.п}$ kcal/kg is determined by pressure and temperature in steam turbine throttle on the tables of appendix II;

$D_{н.п}$ kg/h - quantity of saturated steam, returned besides the superheater, with enthalpy $i_{н.п}$ kcal/kg, determined on the pressure in the boiler barrel;

$D_{пр}$ kg/h - expenditure of water for the blasting of boiler (for the direct-flow/ramjet separator boiler- blasting of separator) with the enthalpy of boiling $i_{кип}$ kcal/kg, determined on the pressure in

the drum (separator) of the boiler;

$i_{п.в}$ - heat content cf feed water on entrance into the aggregate/unit, kcal/kg;

$D_{вт.пе}$ kg/h - flow rate of steam through the secondary superheater with the initial of enthalpy $i'_{вт.пе}$ kcal/kg and final $i''_{вт.пе}$ kcal/kg;

$Q_{отд}$ - heat absorpticn of the water cr air, preheated in the boiler aggregate/unit and loosened to the side, kcal/h.

With the assigned magnitude of blasting less than 2o/o heat consumption per preheating of blowoff water are nct considered.

5-15. Consumption of fuel, supplied to heating, is determined frcm to formula

$$B = \frac{Q_{к.а}}{Q_p^р \eta_{к.а}} \cdot 100 \ \overset{(1)}{кг/час.} \qquad (5\text{-}15)$$

Key: (1). kg/h.

In the case of combusting the mixture of two uniform (for example, solid) fuels/propellants according tc formula (5-15) is determined total consumption of both fuels/propellants. The

consumption of each fuel is determined on the relationship/ratio of quantities of both fuels/propellants accepted (see Sections 2-20 and 2-21).

In the case of combusting the mixture solid (liquid) and gaseous fuels according to formula (5-15) is determined the consumption of solid (liquid) propellant. The consumption of gaseous fuel is determined on the relationship/ratio of quantity of both fuels/propellants accepted (see Section 2-22).

The flow rate of propellant and efficiency of boiler aggregate/unit during the calculation for working fuel in the case of drying by stack gases according to the extended cycle are determined from the formulas:

$$B = B' \frac{100 - W^{p'}}{100 - W^{p}} \overset{(1)}{\text{кг/час}}; \qquad (5\text{-}16)$$

$$\eta_{к.а} = \eta'_{к.а} \frac{B' Q_p^{p'}}{B Q_p^{p}} \%. \qquad (5\text{-}17)$$

Key: (1). kg/h.

where the designations with the prime relate to the latter fuel/propellant, and without the prime - to the working (damp/crude) fuel/propellant. During determination $\eta_{к.а}$ into value $q_4$ conditionally is introduced the loss with the escape of dust from the dust catcher.

5-16. For determining total volumes of ccmbustion products and air, which pass from entire boiler aggregate/unit, and included in them quantities of heat calculated fuel consumption is determined taking into account mechanical inccmpleteness of combustion according to formula

$$B_p = B\left(1 - \frac{q_4}{100}\right) \text{кг/час}^{(1)}, \qquad (5\text{-}18)$$

Key: (1) kg/h.

where B - real consumption of fuel, which enters the boiler aggregate/unit, calculated according to formula (5-15), kg/h.

Subsequently into all formulas for determining of total volumes and quantities of heat is substituted value $B_p$, while into the values of specific volumes and enthalpy cerrection fcr the mechanical incompleteness of combustion is not intrcduced.

The calculation of the system of pulverized coal preparation and fuel feed is conducted according to the actual consumption of fuel B, the calculation of thrust/rod ard blasting - according to the calculated consumpticn of fuel $B_p$.

Chapter Six

CALCULATION OF HEAT EXCHANGE IN HEATING.

6-01. Calculation is based on applications of theory of similarity to burning processes. Calculation formulas link the transmitted in the heating quantity of heat $Q_\text{т}$ kcal/kg and a dimensionless outlet temperature from heating $\theta''_m$ with the basic criteria of similarity of the burning process: by Boltzmann's criterion $Bo$. with absorption strength $ks$. by chemical criterion $\Pi$ and by geometric characteristics $\varepsilon$ and $\rho$.

6-02. Initial for calculation heat transfer in heatings is formula, which is determining dimensionless outlet temperature from heating:

$$\theta''_m = \frac{T''_m}{T_a} = \frac{Bo^{0.6}}{0.445a_m^{0.6} + Bo^{0.6}}, \quad (6\text{-}01)$$

suitable for values $Bo < 10a_m$ or $\theta''_m < 0.9$.

For the pneumatic heatings of Shershnev with the shielded ejector funnels and the anthracitic layer heatings in formula (6-01) the coefficient when $a_m^{0.6}$ instead of 0.445 takes as the equal to 0.54.

Here $a_m$ - emissivity factor of the heating;

$T''_m$ - absolute temperature of gases at the output from the heating, °K;

$T_a$ - absolute theoretical temperature of combustion, conditionally taken the equal temperature which would take place with the adiabatic combustion, °K.

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Theoretical temperature $\vartheta_a$ °C is determined on the useful heat release in heating $Q_m$ kcal/kg, the equal enthalpy of combustion products $I_a$ kcal/kg with temperature $\vartheta_a$ and excess air at the end of heating $a_m$.

6-03. Boltzmann's criterion $B_0$ is calculated according to formula

$$Bo = \frac{\varphi B_p V c_{cp}}{4{,}9 \cdot 10^{-8} \psi H_л T_a^3}, \qquad (6\text{-}02)$$

where $B_p$ - calculated fuel consumption, determined according to formula (5-18), kg/h;

$\psi$ - conditional contamination factor of beam-receiving surfaces;

$H_л$ - beam-receiving heating surface indications regarding which are given in p. 6-15, $m^2$;

$4.9 \cdot 10^{-8}$ - kcal/$m^2$ hour $°K^4$ - radiation coefficient of blackbody;

$Vc_{cp}$ - average/mean total heat capacity of products of combustion 1 kg of fuel/propellant in range of temperatures $\vartheta''_m - \vartheta_a$ kcal/kg deg;

$\varphi$ - coefficient of retention/preservation/maintaining heat, determined according to formula (5-09).

6-04. For practical calculations are applied following formulas.

If is prescribed/assigned the temperature of gases at the output from the heating, then the beam-receiving surface is designed from the formula

$$H_л = 0{,}79 \cdot 10^8 \frac{B_p Q_л}{\zeta a_m T''_m T_a^3} \sqrt[3]{\left(\frac{T_a}{T''_m} - 1\right)^2} \; м^2. \quad (6\text{-}03)$$

If the assigned magnitude of the beam-receiving heating surface, then the temperature of gases at the yield from the heating is determined according to the formula

$$\vartheta_m'' = \frac{T_a}{\left(\frac{1{,}27\cdot10^{-8}\zeta H_л a_m T_a^3}{\varphi B_p V c_{cp}}\right)^{0{,}6} + 1} - 273\,^\circ\mathrm{C}. \quad (6\text{-}04)$$

During the calculation of the pneumatic heatings of Shershnev with the shielded ejector funnels and anthracitic layer heatings numerical coefficients take as equal ones in formula (6-03) 0.60•10⁸ and in formula (6-04) 1.70•10⁻⁸.

For all heatings whose calculation is produced without a change of the coefficients in formulas (6-03) and (6-04), values $\vartheta_m''$ and $H_л$ can be determined according to nomogram 1.

6-05. Average/mean total heat capacity of products of combustion 1 kg of fuel/propellant

$$Vc_{cp} = \frac{Q_m - I_m''}{\vartheta_a - \vartheta_m''} \text{ ккал/кг град}, \quad (6\text{-}05)$$

Key: (1). kcal/kg deg.

where $I_m''$ - enthalpy of the products of the combustion 1 kg of fuel/propellant with temperature $\vartheta_m''$ and excess air at the end of heating $a_m$, kcal/kg.

6-06. Useful heat release in heating

$$Q_m = Q_p^p \frac{100 - q_3 - q_6}{100} + Q_в - Q_{в.вн ш} + r I_{з.отб} \text{ ккал/кг}^{(1)}, \quad (6\text{-}06)$$

Key: (1). kcal/kg.

where $Q_p^p$ - available heat of fuel/propellant, computed from formula (5-02), kcal/kg;

$q_3$ and $q_6$ - heat loss from the chemical incompleteness of combustion, with the physical heat of slags and the cooling water, o/o;

$Q_в$ - heat, introduced into the heating by air, kcal/kg:

$$Q_в = (\alpha_m - \Delta\alpha_m - \Delta\alpha_{пл.у}) I_в^{0''} + (\Delta\alpha_m + \Delta\alpha_{пл.у}) I_{х.в}^0 \text{ ккал/кг}^{(1)}. \quad (6\text{-}07)$$

Key: (1). kcal/kg.

The values of suctions $\Delta\alpha_m$ and $\Delta\alpha_{пл.у}$ are determined on p. 4-16, and the enthalpy of the theoretically necessary quantity of air at an outlet temperature from air preheater $I_в^{0''}$ kcal/kg and cold air kcal/kg are accepted on $I_{х.в}^0$, the table (RN 4-05);

$Q_{в.вн ш}$ - heat, introduced with the entering the aggregate/unit air during its preheating out of the aggregate/unit (see Section 5-03),

kcal/kg;

$I_{г.отб}$ - heat of the recirculating gases, considered only in the case of return into the heating of part cf the gas, selected from the subsequent flues (but not of the heating) (see Section 4-10) kcal/kg.

6-07. Quantity of heat, transmitted in heating on 1 kg of fuel/propellant

$$Q_л = \varphi (Q_т - I''_т) \text{ ккал/кг.} \quad (6\text{-}08)$$

Key: (1). kcal/kg.

6-08. Conditional contamination factor of beam-receiving surfaces, which considers reduction in heat absorption due tc pollution/contamination cr coverage as insulaticn/isolation of surfaces, is received cn table.

| (1) Тип экрана и род топлива | | (2) Условный коэффициент загрязнения ζ |
|---|---|---|
| (3) Открытые гладкотрубные и плавниковые экраны и экраны с чугунными плитами | (4) Газообразное топливо | 1,00 |
| | (5) Жидкое топливо и твердое топливо, сжигаемое в слое | 0,90 |
| | (6) Твердое топливо при камерном сжигании[1] | 0,70 |
| (7) Зашипованные экраны, покрытые хромитовой обмазкой | | 0,20 |
| Экраны, закрытые шамотным кирпичом (8) | | 0,10 |

Key: (1). Type of shield and kind cf fuel/propellant. (20. Conditional contaminaticn factor. (3). open plain-tube and fin shields and shields with cast iron plates/slats. (4). Gaseous fuel. (5). Liquid propellant and sclid fuel, burned in layer. (6). Solid fuel during chamber combustion [1].

FOOTNOTE [1]. The use/application of efficient blasting, included every shift, raises (according to American data) tc 0.75. ENDFOOTNOTE.

(7). studded shields, covered with chromite greasing. (8). Shields, closed with fire brick.

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For the combined heatings (gas-oil or powder-gas) conditional contamination factor should be selected on that fuel/propellant for

which it has smaller value.

For torch- layer heatings with the combustion of fuel/propellant partially in the layer and partially in the chamber/camera is recommended conditional contamination factor to accept the same as for the layer combustion.

6-09. Emissivity factor of heating during even distribution of shields according to its walls is determined by general formula:

$$a_m = \frac{0{,}82\,[a_\phi + (1 - a_\phi)\,\rho\psi']}{1 - (1 - \psi'\zeta)(1 - \rho\psi')(1 - a_\phi)}. \qquad (6\text{-}09)$$

where $a_\phi$ - efficient emissivity factor of flame;

$\psi'$ - degree of shielding of heating:

$$\psi' = \frac{H_s}{F_{cm} - R}, \qquad (6\text{-}10a)$$

$F_{cm}$ - full/total/complete surface of walls of heating (see Section 6-14), m²;

R - area of mirror of combustion of layer of fuel/propellant, situated on fire grate, m²;

$\rho$ - relationship/ratio between surface of mirror of combustion and beam-receiving surface:

$$\rho = \frac{R}{H_{\text{л}}};\qquad (6\text{-}11)$$

0.82 - value of absorptivity cf beam-receiving heating surface accepted.

Value $H_{\text{л}}$ is determined on the indications p. 6-15.

In the absence of burning radiation layer formula (6-09) takes the form:

$$a_m = \frac{0{,}82 a_\phi}{a_\phi + (1 - a_\phi)\psi\zeta}. \qquad (6\text{-}12)$$

and the degree of shielding $\psi$ passes into the degree of the shielding of the chamber furnaces:

$$\psi = \frac{H_{\text{л}}}{F_{cm}}. \qquad (6\text{-}10б)$$

When, in the layer or chamber furnaces, the beam-receiving surfaces are present, with the different values of ccnditional contamination factor $\zeta$ one should determine

$$\psi\zeta = \frac{\Sigma(\zeta H_{\text{л}})}{F_{cm}}. \qquad (6\text{-}10в)$$

According to formula (6-12) is constructed that led in RN of 6-02 graphs/curves for determining emissivity factor of chamber furnaces.

Formula (6-12) is used for calculating emissivity factor of the chamber furnaces, in which they are shielded more than two planes, which limit heating.

If the beam-receiving surface is arranged/located only in by output section/cut of chamber furnace or occupies exit section and one of the walls, then emissivity factor of heating is designed according to the formula

$$a_m = \frac{0{,}82a_\phi(1 - a_\phi\psi\zeta)}{a_\phi + (1 - 2a_\phi)\psi\zeta}, \qquad (6\text{-}13)$$

of obtained under the assumption about position of all screen surfaces on one wall heating.

Emissivity factor of the layer « flame-layered heatings calculated according to formula (6-09).

6.10. Efficient emissivity factor of flame $a_\phi$ depends on emissivity factor of furnace medium a, degree of filling of heating with luminous flame and character of temperature field of heating.

Emissivity factor of the furnace medium

$$a = 1 - e^{-kps}. \qquad (6\text{-}14)$$

where e - a Naperian base;

k - coefficient of weakening rays/beams by the furnace medium;

p - pressure in heating, atm(abs.); for the boilers, which work without the supercharging/pressurization, the pressure in the heating is received equal to 1 atm(abs.);

s - efficient thickness of radiation layer (see Section 6-12), m.

According to formula (6-14) is constructed the auxiliary graph of nomogram XI for determining emissivity factor of medium.

The effect of the degree of the filling of heating with luminous flame and character of temperature field to efficient emissivity factor of flame $a_\phi$ is considered by correction factor β.

Efficient emissivity factor of the flame

$$a_\phi = \beta a. \qquad (6\text{-}15)$$

Coefficient β depends on the form of flame which in turn, is

determined by the kind of fuel/propellant and by the method of its combustion.

Are distinguished three forms of the flame:

a) the nonluminous flame, which is obtained during the combustion of gaseous fuels [1], and also the layer and flame- layer combustion of anthracite and lean carbon/coals;

b) the full heat, which is obtained during the chamber combustion of anthracite and lean coal;

c) the luminous flame, which is obtained with combustion of liquid propellants [2] and solid fuels, rich in volatile components.

FOOTNOTE [1]. Usually during the combustion of gas in the heatings of steam boilers flame noting glow. Only sometimes of combusting rich in hydrocarbons gas is formed the glowing sooty flame whose radiation/emission corresponds to the radiation/emission of luminous flame of liquid propellants.

[2]. During combustion of petroleum residue with very low thermal loads ($\frac{Q}{V} < 25 \cdot 10^{4}$ kcal/m³ hour) luminous flame occupies very small part of furnace cavity. Therefore the total radiation of flame in the case in question differs little from the radiation/emission of nonluminous flame. ENDFOOTNOTE.

Values β are selected cn the table.

| (1) Вид пламени | β |
|---|---|
| (Несветящееся (2) | 1,00 |
| Светящееся жидких топлив (3) | 0,75 |
| Светящееся и полусветящееся твердых топлив (4) | 0,65 |

Key: (1). Form of flame. (2). Noting glow. (3). Glowing of liquid propellants. (4). Glowirg and semiluminous solid fuels.

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During the combusticn of the mixture of the fuels/propellants, which have different luminous density of flame, efficient emissivity factor of flame is designed for the fuel/propellant, characterized by the larger luminous density of flame.

6-11. Coefficient cf weakening rays/beams by furnace medium k is designed at outlet temperature from heating.

a) for the nonluminous flame it takes as the equal to the coefficient of weakening rays/beams by the triatomic gases:

$$k = k_r r_n = \frac{0{,}8 + 1{,}6 r_{H_2O}}{\sqrt{p_n s}} \left(1 - 0{,}38 \frac{T''_m}{1000}\right) r_n, \tag{6-16}$$

where the total volume fracticn of the triatcmic gases

$$r_n = r_{H_2O} + r_{RO_2};$$

volume fractions $H_2O$ and $RO_2$ are determined on RN 4-01;

the total partial pressure of triatomic gass

$$p_n = pr_n \overset{(1)}{ama.}$$

Key: (1). atm(abs.).

For the boilers, which work without the supercharging/pressurization, partial pressure is numerically equal to volume fraction.

Value $k_r$ can be determined according to nomogram IX.

b) for the full heat value k takes as the equal to the coefficient of weakening rays/beams by triatomic gases and incandescent ash particles:

$$k = k_r r_n + k_n\mu = \frac{0{,}8 + 1{,}6 r_{H_2O}}{\sqrt{p_n s}} \left(1 - 0{,}38 \frac{T''_m}{1000}\right) r_n + 7{,}0\mu \sqrt[3]{\frac{1}{d_n^2 T''^2_m}}, \qquad (6\text{-}17)$$

where $d_n$ - the mean effective diameter of the particles of the ash (see Section 7-36), mkn;

$\mu$ - ash concentration in the flue gases with the excess air at the end of the heating, determined on p. 4-02, g/nm³.

Value $k_n$ can be determined according to nomogram X.

c) for the luminous flame value k is equal to the coefficient of weakening rays/beams by the sooty particles:

$$k = 1{,}6\frac{T''_m}{1\,000} - 0{,}5. \qquad (6\text{-}18)$$

For the heatings with the luminous flame (during the combustion of liquid propellants and solid fuels, rich in volatile components) with s>2.5 m it is accepted that a=1, and values k determined must not be.

6-12. Efficient thickness of radiation layer of flame is determined from formula

$$s = 3{,}6\frac{V_m}{F_{cm}}\ m. \qquad (6\text{-}19)$$

where $V_m$ - active volume of furnace chamber/camera, determined on p. 6-13, m³;

$F_{cm}$ - full/total/complete surface of walls of heating, determined on

p. 6-14, $m^2$.

6-13. Sensitive volume of furnace chamber/camera $V_m$ $m^3$ is determined in accordance with diagrams RN 6-03.

By the boundaries/interfaces of sensitive volume are the walls of furnace chamber/camera, and in the presence of shields - axial planes of screen ducts or converted into the heating surfaces of insulating or protective layer. Sensitive volume is limited also to the surface. passing through first run of pipes of boiler bundle, scallop [festoon] or screen surfaces (pos. 3 and 4 RN 6-03), by the horizontal plane, which separates/liberates the lower half cold funnel (pos. 5), by the surface of the layer of fuel/propellant or by the ducts of granulator (pos. 8).

For the heatings in which the flame is developed in the slag funnel, for example heatings with an inclined-horizontal hearth or heatings of Shershnev, in the active furnace cavity is included the full/total/complete volume of slag funnel.

In accordance with the determination of sensitive volume for the layer heatings from the volume, bounded below by the plane of grate bar fabric, is eliminated the volume of the layer of fuel/propellant and slag whose average/mean thickness takes as the equal: for coals -

150-200 mm, for the brown coal - 300 mm, for the wood chips - 500 mm, for the peat - in depending on the position of the beam/gully, which limits the output/yield of fuel/propellant to the fabric (pos. of 7 BN 6-03).

The chamber/camera between the ducts of boiler bundle and the front wall is included in the volume of heating with its width not less than 0.5 m (pos. 1 and 2).

In the layer heatings the volume of heating is limited to the vertical plane, passing through the ends of the grate bars, scrapers of clinker arrester or elements/cells of slag backwater (pos. 6).

6-14. Full/total/complete surface of walls of heating $F_{cm}$ m² is calculated from superficial dimensions, which limit sensitive volume of furnace chamber/camera (BN 6-03).

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In the presence of the shield of bilateral irradiation to actual area of walls is added the doubled product of the distance between centers of boundary tubes of this shield to the illuminated length of ducts.

6-15. Beam-receiving surface of heating $H$, m² is defined as value of continuous plane which on heat reception is equivalent to real uncontaminated and uncovered screen surface, and is designed from formula

$$H_{A} = \Sigma F_{n.A} x \ m^2, \qquad (6\text{-}20)$$

where $F_{n.A}$ - area of wall, occupied with shield, m²;

x - angular coefficient of shield.

The area of wall, occupied with shield, $F_{n.A}$ is defined as the product of the distance between centers of boundary tubes of this shield b m to the appropriate illuminated length of screen ducts l m:

$$F_{n.A} = bl \ m^2.$$

The illuminated length of screen ducts $l$ m is limited to the same limits to which is limited the considered during the calculation of the sensitive volume of furnace chamber/camera part of the volume of heating.

The methods of determining the illuminated length of ducts for different encountered in the practice cases are shown in RN 6-03.

For the shield of bilateral irradiation it is accepted

$$F_{n.s} = 2bl \ м^2.$$

From value $F_{n.s}$ are eliminated unprotected by ducts the sections of wall if the area of each of them is more than 1 m².

The angular coefficient of shield x is defined as the relation between the quantity of heat, received by the ducts of shield, and a quantity of heat which would take the shielded wall if it was the continuous plane, which has the temperature, equal to the temperature of screen ducts.

The angular coefficient of plain-tube shields in depending on their structural/design characteristics is determined on the curves RN 6-02. For the wall shields it is accepted taking into account the radiation/emission of bricking, while for the shields of bilateral irradiation - without taking into account the radiation/emission of bricking.

For the plain-tube shields, comprised of the alternating ducts of different diameters, the angular coefficients of entire shield x and separately the ducts of the small diameter $x_1$ are determined on Fig. 2c RN 6-02. In this case the beam-receiving surface of entire shield is defined as product $F_{n.s}x$ m², and the beam-receiving surface

of the ducts of a small diameter - as $F_{n.s}x_1$ m², where $F_{n.s}$ - area of the entire wall, occupied with shield.

For the studded and fin shields, and alsc for the shields, closed with cast iron plates/slabs, angular cceffficient takes as the equal to unit.

For the surface, passing through first run of pipes of bciler bundle, scallop and screens, angular coefficient is also equal to one. During the calculation of the subsequent heating surfaces one should consider that the angular coefficient cf bundle itself or scallop can be less than the unit and the part cf the falling/incident heat is passed through the tundle to arranged/located after it surface cf heating.

The angular coefficient of double-rcw bundle, necessary for calculating a quantity cf that passing through the bundle of heat, is determined on curved 3 Fig. __ 2b BN 6-02.

The angular coefficient of bundle with a number of series/rows z>2 approximately is designed frcm the fcrmula

$$x_{nyq} = 1 - (1 - x_1)(1 - x_2)\dots(1 - x_z), \quad (6\text{-}21)$$

where $x_1$, $x_2$, ..., $x_z$- angular coefficients of separate runs cf

pipes, determined in curved 5 Fig. 2a RN 6-02.

In the presence in heating beam-receiving surfaces with the different values of conditional contamination factor $\zeta$ into formulas (6-03) and (6-04) instead of $\zeta H_A$ is introduced $\Sigma(\zeta H_A)$.

6-16. During calculation of heatings, which work on liquid propellant with excess air, by those differing significantly from normal ones ($\alpha_m < 1.10$ or $\alpha_m > 1.35$), dimensionless outlet temperature from heating is determined from formula

$$\theta_m'' = \frac{(\Pi Bo)^{0.6}}{0.445\alpha_m^{0.6} + (\Pi Bo)^{0.6}}, \qquad (6\text{-}22)$$

where $\Pi$ - chemical criterion, which considers effect of excess air ratio $\alpha_m$ on temperature field of heating:

$$\Pi = \frac{1.3\alpha_m^2}{\alpha_m^2 + 2(\alpha_m - 1)}. \qquad (6\text{-}23)$$

6-17. In heatings of ship steam boilers, which work on liquid propellant without supercharging/pressurization, with reduction in boiler steam capacity due to cutoff/disconnection of part of injectors deteriorates filling of furnace cavity with flame. In this case with the thermal stresses of the surface of the walls of the furnace chamber/camera

$$\frac{BQ_н^р}{F_{cm}} < 0.8 \cdot 10^6 \text{ ккал/м}^2 \text{ час в формулу (6-01)}$$

Key: (1). kcal/m²h into the formula

instead of coefficient cf 0.445 should be introduced the variable coefficient of A, determined according tc the approximation formula

$$A \approx \frac{1}{0{,}7 + 2\cdot 10^{-6}\frac{BQ_n^p}{F_{cm}}}. \qquad (6\text{-}24)$$

6-18. In pulverized-coal ccmbustors with tangential burners change in angle of slope of burners affects filling of furnace cavity with flame. This is considered in the calculations by the replacement of coefficient of 0.445 in formula (6-01) by value 0.5 during the rotation of burners on 30° downward even 0.4 - during the rotation on 30° upward from the horizontal plane.

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6-19. If necessary for refinement of thermal loads of beam-receiving surfaces in individual sections of walls of heating (for example, for calculating of radiaticn and screen superheaters, etc.) thermal load is determined from equality

$$q = y\frac{B_p Q_\text{л}}{H_\text{л}} \text{ ккал/м}^2\text{ час}, \qquad (6\text{-}25)$$

Key: (1). kcal/m²h

where $y$ - variation factor of heat distribution in the furnace chamber/camera;

$\frac{B_p Q_л}{H_л}$ - average thermal load of beam-receiving surfaces, kcal/m²h.

In the presence in heating of the beam-receiving surfaces with the different values of conditional contamination factor $\zeta$ the thermal load is determined from to the formula

$$q = y\frac{B_p Q_л}{\Sigma(\zeta H_л)}\zeta_{уч}\ \overset{(1)}{ккал/м^2\,час}, \quad (6\text{-}25a)$$

Key: (1). kcal/m²h

where $\zeta_{уч}$ - conditional contamination factor of this section.

Value y is accepted on the basis of the following tentative recommendations.

For upper fourth of all walls of chamber furnaces (counting on the overall height of heating) during the combustion of solid fuels y=0.75, for upper third y=0.8; for ceiling y=0.6.

In the mazut heatings of boilers with D>12 t/h with the thermal stresses of volume ≤250•10³ kcal/m³h for ceiling y=0.5 and for upper fourth of the walls, y=0.6. With the higher thermal loads of furnace chamber/camera the load distribution

according to the height cf heating will be more uniform.

The distribution of thermal lcads according to the shields, arranged/located on the different walls cf heating, depends substantially on the type of fuel/propellant and conditions of the course of burning process.

Due to the absence cf reliable experimental data at present it is possible to only assume that for the completely slag screened fireboxes with the front arrangement of burners the load of rear shield 20o/o by approximately exceeds average, and the load of front shields can compose 80-100o/o of average.

With the tangential burners it is pcssible to expect that the distribution of thermal loads according to the walls of heating approaches uniform.

During the definiticn of the heat absorption of separate screen surfaces should be considered the nonuniformities of the distribution of thermal loads both according to the perimeter and according to the height of heating. The distribution accepted must be checked, composing the balance of radiation heat absorption.

# Chapter Seven.

## CALCULATION OF THE CONVECTIVE HEATING SURFACES.

### 7-A. Main equations.

7-01. For calculating convective heating surface are used two equations.

Equation of the heat exchange:

$$Q = \frac{kH\Delta t}{B_p} \text{ ккал/кг}, \qquad (7\text{-}01)$$

Key: (1). kcal/kg.

where Q - the heat, taken by the designed by surface convection and radiation referred to 1 kg ($nm^3$) of fuel/propellant, kcal/kg;

k - coefficient of heat transfer, in reference to the calculated surface, heating, kcal/$m^2$ hour deg;

H - calculated heating surface, usually taken equal surface from the external (gas) side, the $m^2$; for the tubular air preheaters the heating surface is received as average along the air and gas sides;

for the first bundles and the screen superheaters, which obtain heat by radiation/emission from the furnace chamber/camera, for the calculated heating surface is accepted the difference between the full/total/complete heating surface and the efficient beam-receiving surface;

$\Delta t$ - temperature head, °C;

$B_p$ - calculated consumption of fuel, kg/h.

7-02. Equation of heat balance, in which are equated heat, returned by gases, and heat, taken by vapor, water or air:

$$\varphi(I' - I'' + \Delta\alpha I^0_{npc}) = Q \overset{(1)}{\text{ккал/кг}}, \quad (7\text{-}02)$$

Key: (1). kcal/kg.

where $\varphi$ - coefficient of the retention/preservation/maintaining heat, which considers the heat losses into the environment (RN 5-01);

I' and I" - the enthalpy of gases on the entrance into the heating surface and the output from it, kcal/kg;

$\Delta\alpha I^0_{npc}$ - quantity of heat, introduced by the sucked air, kcal/kg;

$t^0_{npc}$ - is determined on the table:

for the air preheater according to mean temperature of the air

$$t = \frac{t'_{en} + t''_{en}}{2};$$

for all remaining flues - according to the temperature of cold air $t_{x.e}$.

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7-03. Heat, taken by heating medium, Q is determined from following formulas:

for superheater

$$Q = \frac{D}{B_p}(i'' - i') - Q_A \overset{(1)}{\text{ккал/кг}} \quad (7\text{-}03a)$$

Key: (1). kcal/kg

(here from the value of heat absorption is conditionally subtracted the heat, obtained by the radiation/emission from furnace, $Q_A$, kcal/kg);

for the economizer and the transient zone of single-pass boiler

$$Q = \frac{D}{B_p}(i'' - i')\ ккал/кг^{(1)}, \quad (7\text{-}03б)$$

Key: (1). kcal/kg

where D - consumption of steam (water) through designed surface, kg/h;

i" and i' - enthalpy of steam (water) on the output from the heating surface and entrance into it, kcal/kg.

For the superheater a drop/jump in the enthalpy of steam should be accepted taking into account the heat absorption of the steam cooler (for greater detail, see p. 8-39).

For the air preheater

$$Q = \left(\beta''_{вп} + \frac{\Delta\alpha_{вп}}{2}\right)(I^{0''}_{вп} - I^{0'}_{вп})\ ккал/кг^{(1)}, \quad (7\text{-}04)$$

Key: (1). kcal/kg

where $\beta''_{вп}$ - ratio of a quantity of air at the output from air heater to theoretically necessary;

$I^{0''}_{вп}, I^{0'}_{вп}$ - enthalpy of air, theoretically necessary for the combustion, with the outlet temperatures from the air preheater and

entrance into it, kcal/kg;

$\Delta\alpha_{вп}$ - suction of air in the air preheater, taken to the equal to leakage from the air side.

For the boiler bundles of nonducted boilers the equation of the heat absorption of heating medium is absent.

7-04. If designed heating surface washes by incomplete quantity of combustion products (parallel connection of several elements/cells, bypass damper control, bypass flues in presence of not completely dense dampers, etc.), equation (7-02) is replaced by following:

$$Q = \varphi\,(I' - I'' + \Delta\alpha I^{0}_{прс})\, g_{п} \text{ ккал/кг}^{(1)}. \quad (7\text{-}05)$$

Key: (1). kcal/kg.

where $g_{п}$ the weight share of the gases, passing through the shunted bundle.

With the parallel connection of several elements/cells or open bypass flues $g_{п}$ it is determined from the formula

$$g_{п} = \frac{F_{п}}{F_{р}}. \quad (7\text{-}06)$$

where $F_n$ - the clear opening of bundle (shunted flue), m²;

$F_p$ - a calculated fully clear opening, m².

This value is determined taking into account the relationship/ratio of resistances of parallel gas conduits.

The determination of clear openings see p. 7-18.

With the double dense closed disconnecting dampers in bypass flues $g_n$ it takes as the equal to 0.95, with the single dampers - 0.9.

After the calculation of the heating surface are determined the enthalpy and the temperature of the mixture of main gas flow with the part, which passed besides the designed heating surface.

Equation of shift

$$I_{см} = I'(1 - g_n) + I''g_n \text{ ккал/кг}^{(1)}. \quad (7\text{-}07)$$

Key: (1). kcal/kg.

7-B. THE COEFFICIENT OF HEAT TRANSFER.

a) basic condition/positions.

7-05. Coefficient of heat transfer for multilayer flat/plane wall is expressed by formula

$$k = \frac{1}{\frac{1}{\alpha_1} + \frac{\delta_з}{\lambda_з} + \frac{\delta_м}{\lambda_м} + \frac{\delta_н}{\lambda_н} + \frac{1}{\alpha_2}} \overset{(1)}{\text{ккал/м}^2\text{ час град.}} \quad (7\text{-}08)$$

Key: (1). kcal/m²h deg.

For all usually encountered in the boiler aggregates/units plain-tube surfaces it is possible to use this formula. The special features/peculiarities, which relate to the separate types of the heating surfaces, are shown below in paragraphs 7-08-7-14.

$a_1$ and $a_2$ - heat-transfer coefficients from the heating medium to the wall and from the wall to the heating medium, the kcal/m² hour deg;

$\delta$ m and $\lambda$ kcal/m hour deg - thickness and coefficients of the thermal conductivity: $\delta_з$ and $\lambda_з$ the layer of ash and carbon black on the external surface of the duct; $\delta_м$ and $\lambda_м$ - wall of the duct; $\delta_н$ and $\lambda_н$ - scale deposit on the internal surface of duct.

7-06. Heat-transfer coefficient from gases to wall

$$\alpha_1 = \omega\alpha_к + \alpha_л \quad \overset{(1)}{\text{ккал/м}^2\text{ час град,}} \quad (7\text{-}09)$$

Key: (1). kcal/m² hour deg

where $\omega$ - coefficient cf flow, which considers the decrease of the heat absorption of the heating surface as a result of the inccmplete flow by its gases.

The incomplete sweep of gases of the heating surface occurs in such cases the code the configuration of bundle and placement of barriers they allow/assume the fcrmation of the gas pockets, the clearly expressed nonuniformity of flow cver the section/cut or partial gas overflow besides the bundle. A ncticeable reduction in the heat absorption is cbserved only with the gas overflow besides the bundle, which usually is not allowed/assumed.

In the case of the ncnuniformity of flow over the secticn/cut the effect of the incompleteness of flow in essence is compensated due to an increase in the speed in the washed part. Therefore the coefficients of the flcw of the boiler heating surfaces, is especially the transversely washed beams of mcdern aggregates/units of average/mean and large power, are close tc the unit.

For the most characteristic ccnstructicns/designs of the

incorrectly washed bundles the coefficients of flow $\omega$ are given in BN 7-03. Is there shown the method of determining the calculated open r passage sections/cuts for these bundles.

$\alpha_k$ - convection heat-transfer coefficient, determined in Section .6. kcal/m²h deg;

$\alpha_l$ - radiation heat-transfer coefficient, the determined in Section .8. kcal/m² hour deg.

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7-07. Thermal resistance of contaminating layer on external surface of duct $\frac{\delta_3}{\lambda_3}$, called contamination facter $\varepsilon$, is determined on Section .7. of present paragraph.

7-08. Value $\alpha_2$ is determined on Section .6. of present paragraph. In the calculations of economizers and evaporative surfaces, as a result of the fact that $\alpha_2 \gg \alpha_1$, thermal resistance from internal side they disregard.

7-09. Resistance of thermal conductivity in metal of wall of smooth pipes almost in all cases (with exception of steam coolers) in calculation is not considered.

7-10. Resistance of scale deposit on internal surface of ducts in boiler aggregates/units of average/mean and high pressure, which work during scale-free mode/conditions, virtually is absent.

In low-pressure boilers the scale formation is possible, but during the normal operation it must not reach the sizes/dimensions, which call a noticeable increase in the thermal resistance of wall. Therefore resistance of scale deposit usually into the calculation is not introduced.

7-11. In conformity with paragraphs 7-07-7-10 calculation of the coefficient of heat transfer in the plain-tube bundles is produced according to the formulas:

for the superheaters

$$k = \frac{\alpha_1}{1 + \left(\varepsilon + \frac{1}{\alpha_2}\right)\alpha_1} \text{ (1) ккал/м}^2 \text{ час град;} \quad (7\text{-}10a)$$

Key: (1). kcal/m² hour deg

for the economizers and the evaporative surfaces

$$k = \frac{\alpha_1}{1 + \varepsilon\alpha_1} \text{ (1) ккал/м}^2 \text{ час град.} \quad (7\text{-}10б)$$

Key: (1). kcal/m² hour deg.

7-12. During calculation of air preheaters, in view of absence of data for determining contamination factor and account of other deviations from design conditions, is introduced general/common/total coefficient of use of heating surface. In this case the coefficient of heat transfer is determined from to the formula

$$k = \xi \frac{\alpha_1 \alpha_2}{\alpha_1 + \alpha_2} \text{ ккал/м}^2 \text{ час град}^{(1)}, \quad (7\text{-}11)$$

Key: (1). kcal/m² hour deg

where $\xi$ - coefficient of use, determined within section «д».

7.13. The method of determining the coefficient of heat transfer of ribbed surfaces of heating having a number of special features is given in section «г» of this paragraph.

7-14. Coefficient of heat transfer" in revolving regenerative air heaters with lamellar packing, referred to full/total/complete heating surface, is determined from to formula

$$k = \frac{1}{\frac{1}{x_1 \alpha_1} + \frac{1}{x_2 \alpha_2}} \text{ ккал/м}^2 \text{ час град}^{(1)}, \quad (7\text{-}12)$$

Key: (1). kcal/m² hour deg

where $x_1 = \frac{H_r}{H}$ - the ~~share~~ portion of the heating surface, washed by the ~~air~~ gasses;

$x_2 = \frac{H_s}{H}$ - the portion of the heating surface washed by air;

$\alpha_1$ and $\alpha_2$ - heat-transfer coefficients from the gases to the wall and from the wall to the air, determined in Section «5» of

present paragraph, kcal/m² hour deg.

The total surface of heating of the regenerative air heaters is taken equal to the two-sided surface of all the packing plates.

b) Convection heat-transfer coefficient.

7-15. Convection heat-transfer coefficient depends on speed and temperature of flow, determining linear dimension, run of pipes in bundle, kind of surface (smooth or finned) and of character of flow its (longitudinal, transverse or oblique), physical properties of washing medium and - sometimes - temperature of wall.

7-16. Rated speed of liquid or gas is determined from to formula

$$w = \frac{V_{сек}}{F} \text{ м/сек}, \qquad (7\text{-}13)$$

Key: (1). m/s.

where F - an area of clear opening m² (neq)

$V_{сек}$ - an average/mean volumetric flow rate per second, m³/s.

7-17. For smoke gases

$$V_{сек} = \frac{B_p V_r (\vartheta + 273)}{3\,600 \cdot 273} \text{ м}^3\text{/сек}, \qquad (7\text{-}14)$$

Key: (1). the m³/s

where $B_p$ - calculated consumption of fuel, kg/h;

$V_2$ - volume of gases per 1 kg of fuel/propellant, determined on the average/mean excess air between entrance a' and output a", nm³/kg.

With the passage through the designed flue only of part of the gas the right side of formula (7-14) is multiplied by $g_n$ [see formula (7-06)].

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For the air

$$V_{cek} = \frac{B_p \beta_{en} V^0 (t + 273)}{3600 \cdot 273} \text{ м}^3/\text{сек}^{(1)}, \quad (7\text{-}15)$$

Key: (1) the $m^3/s$

where $V^0$ - the theoretically necessary for the combustion quantity of air, $nm^3/kg$;

$\beta_{en}$ - ratio of a quantity of air, passing through the air preheater, to theoretically necessary:

$$\beta_{en} = \beta''_{en} + \frac{\Delta\alpha}{2} + \beta_{pu}; \quad (7\text{-}16)$$

$\beta''_{вп}$ - ratio of a quantity of air to theoretically necessary for output from the designed step/stage of the air preheater;

$\Delta\alpha$ - suction in the designed step/stage cf the air preheater;

$\beta_{рц}$ - share of air (thecretically necessary), which goes for the recirculation.

For the water vapcr and the water

$$V_{сек} = \frac{Dv}{3\,600}\ м^3/сек.^{(1)} \qquad (7\text{-}17)$$

Key: (1). the $m^3/s$

D - the hourly consumpticn of vapor or water, kg/h;

v - average/mean specific volume of vapcr or water, $m^3/kg$.

7-18. Clear area for pass cf gases and air in flues, filled transversely and with slantwise streamlined smooth and finned tubes, is determined over secticn/cut, passing through axes/axles of transverse run of pipes as difference between full/total/complete area of cross section of flue in light/wcrld and part of this area, occupied with ducts and partly this area, occupied with ducts and edges/fins. In that indicated, section/cut the area for the pass of

gases is smallest in comparison with any other parallel section/cut. This principle of minimum flow area is accepted also in other cases of determining the speed.

Are given below formulas for determining the calculated clear opening of different types of the heating surfaces.

For the transversely washed plain-tube bundles

$$F = ab - z_1 dl \text{ м}^2, \qquad (7\text{-}18)$$

where a and b - sizes/dimensions of flue calculated cross-section, m;

$z_1$ - number of ducts in the series/row;

d and $l$ - diameter and the length of ducts, m; with bent tubes for value $l$ is accepted the projection of ducts (Fig. 2).

With the longitudinal flow:

with leakage of the medium within the ducts

$$F = z\frac{\pi d^2_{\text{вн}}}{4} \text{ м}^2, \qquad (7\text{-}19)$$

where z - a number of in parallel connected ducts;

during the flow of tne medium between the ducts

$$F = ab - z\frac{\pi d^2}{4} м^2, \quad (7\text{-}20)$$

where z - a number of ducts in the bundle;

$d_{вн}$ - tube bore, m.

For beams of ducts with the cross ribs

$$F = \left[1 - \frac{1}{s_1/d}\left(1 + 2\frac{h_{p6}}{s_{p6}}\cdot\frac{\delta_{p6}}{d}\right)\right] ab\ м^2, \quad (7\text{-}21)$$

where $s_1$ - the transverse pitch of ducts, m;

while d- diameter of carrying duct, m;

$h_{p6}$ and $\delta_{p6}$ - height and average/mean thickness of edge/fin, m;

$s_{p6}$ - step/pitch of edges/fins, m.

The averaging of clear openings with their different value in the individual sections cf the designed flue is produced from the condition of the arithmetical averaging cf speeds, which is equivalent to the arithmetical averaging of values 1/F.

If in this flue are several sections with the identical character of the flow of the heating surface, but by different clear openings, into the calculation is introduced the average/mean cross-sectional area, determined according to the formula

$$F_{cp} = \frac{H_1 + H_2 + \dots}{\frac{H_1}{F_1} + \frac{H_2}{F_2} + \dots} \; м^2. \qquad (7\text{-}22)$$

where $H_1$, $H_2$... $m^2$ - surfaces of heating sections with clear openings $F_1$, $F_2$, ...$m^2$.

With different ones input $F'$ and output $F''$ beam sections in the case of a steady change in the section/cut the averaging is produced according to the formula

$$F_{cp} = \frac{2F'F''}{F' + F''} \; м^2. \qquad (7\text{-}23)$$

In the presence of the disagreement in the cross-sectional area not more than -25o/o it is possible to produce the arithmetical averaging of sections/cuts.

In the presence in bundle of the gas corridors or with the in parallel connected flues calculated clear opening is determined from the formula

$$F_{cp} = F_n + F_м \sqrt{\frac{\zeta_n (\vartheta_n + 273)}{\zeta_м (\vartheta_м + 273)}} \; м^2. \qquad (7\text{-}24)$$

where $F_n$ and $F_w$ - clear area of bundle and shunting flue, $m^2$;

$\zeta_n$ and $\zeta_w$ - coefficients of hydraulic resistances of beam and shunting flue;

$\theta_n$ and $\theta_w$ - mean temperatures of gases in the bundle and the shunting flue, °C.

Diagrams for the selection of the calculated clear openings of the complicatedly washed bundles are given in RN 7-03.

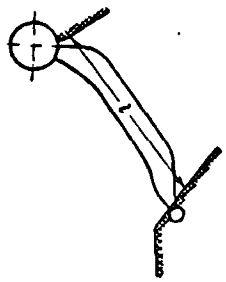

Fig. 2. Determination of the calculated length of ducts. (For determining the surface of heating is considered the effective length of ducts).

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7-19. Calculated temperature of flow of gases is equal to sum of mean temperature of heating medium and temperature head. For the surfaces of heating boiler aggregates/units the calculated temperature of flow can be with sufficient precision/accuracy defined as the half-sum of the temperatures of gases at the entrance into the surface of heating $\vartheta'$ and the output from it $\vartheta''$ according to the formula

$$\vartheta = \frac{\vartheta' + \vartheta''}{2}\ ^\circ\text{C}. \qquad (7\text{-}25)$$

7-20. Calculated determining linear dimension is accepted in dependence on construction/design of surface of heating and character

of flow. Its selection is shown in each of the cases considered/examined below of heat exchange.

7-21. Convection heat-transfer coefficient with transverse flow of corridor bundles is determined from tc formula [1]

$$\alpha_{\kappa} = 0{,}177 C_z \frac{\lambda}{d} \left( \frac{wd}{\nu} \right)^{0{,}64} \text{ ккал/м}^2 \text{ час град}, \quad (1) \tag{7-26}$$

Key: (1). kcal/m² hour deg.

where $C_z$ - correction fcr a number of transverse runs of pipes, determined on nomogram II in the dependence cn an average number of series/rows the separate bundles of the designed bundle; with one run of pipes $\alpha_\kappa$ it is determined cn ncmogram III;

λ - coefficient of thermal conductivity at mean temperature of flcw, determined on p. 3-05, kcal/m hour deg;

ν - kinematic viscosity coefficient at mean temperature of flow, on p. 3-03, m²/s;

d - diameter of ducts, m;

w - gas velocity, cn BN 7-C4, m/s.

FOOTNOTE [1]. Formulas for determining the convection heat-transfer coefficients with the transverse flow are substantiated by the investigations, carried cut at criterion value of Reynolds $Re=(4-65)\cdot 10^2$ for the corridor cnes and $Re=(2-65)\cdot 10^2$ for the checkered bundles. In the usually encountered cases of calculating the boiler aggregates/units it is not necessary to exceed the limits of the values Re indicated; therefore the special testing of applicability for formula it is not required. ENDFOOTNOTE.

According to formula (7-26) is constructed nomogram II for determining of heat-transfer coefficient with the transverse flow corridor bundles. In this and subsequent nomograms the effect of changes of the physical characteristics from temperature and composition of gases to the heat-transfer coefficient is considered with the help of coefficient $C_\phi$.

For the boilers, which work with the supercharging/pressurization, the convection heat-transfer coefficient can be determined on the same nomogram. In this case the speed must conditionally be designed from the volume of gases at the atmospheric pressure. This observation relates also to another cases of the convective heat exchange.

7-22. Convection heat-transfer coefficient with transverse flow

of checkered bundles [2] is determined according to following formulas:

with $$\frac{\frac{s_1}{d}-1}{\frac{s_2'}{d}-1}\leqslant 0{,}7$$

$$\alpha_к = 0{,}270 C_z \frac{\lambda}{d}\left(\frac{wd}{\nu}\right)^{0{,}6} \text{ ккал/м}^2\text{ час град}^{(1)}; \quad (7\text{-}27)$$

Key: (1). kcal/m²h deg

with $$\frac{\frac{s_1}{d}-1}{\frac{s_2'}{d}-1}>0{,}7$$

$$\alpha_к = 0{,}295 C_z \frac{\lambda}{d}\left(\frac{wd}{\nu}\right)^{0{,}6}\left(\frac{\frac{s_1}{d}-1}{\frac{s_2'}{d}-1}\right)^{0{,}25} \text{ ккал/м}^2\text{ час град}^{(1)}, \quad (7\text{-}28)$$

Key: (1). kcal/m²h deg,

where $c_z$ - correction for a number of transverse runs of pipes, determined on nomogram III;

$\frac{s_1}{d}$ - average/mean relative transverse pitch of the ducts;

$\frac{s_2'}{d}$ - average/mean relative diagonal spacer of the ducts:

$$\frac{s_2'}{d}=\sqrt{\frac{1}{4}\left(\frac{s_1}{d}\right)^2+\left(\frac{s_2}{d}\right)^2}; \quad (7\text{-}29)$$

$\frac{s_2}{d}$ - the average/mean relative longitudinal pitch of ducts.

FOOTNOTE [2]. The moved checkered bundle with $s_1/d=1.74$ and $s_2/d=1.5$, used in the sectional boilers, is designed as common checkered bundle. ENDFOOTNOTE.

Remaining designations see p. 7-21.

According to formulas (7-27) and (7-28) is constructed nomogram III for determining the heat-transfer coefficient with the transverse flow of checkered bundles. Graph for determining coefficient $c_s$ is constructed taking into account formula (7-29).

7-23. With variable in depth or width of flue spacings between tubes of designed bundle into calculation are introduced averaged over heating surface steps/pitches:

$$s_{cp}=\frac{s'H'+s''H''+\dots}{H'+H''+\dots}\ м, \qquad (7\text{-}30)$$

where H' and H" m² - surfaces of heating parts of bundle with steps/pitches s' and s".

7-24. In presence in flue of several sections with identical character of flow and different diameters of ducts calculation is conducted according to that averaged proportional to surfaces of heating sections to diameter. In this case are neutralized values 1/d and calculated diameter is determined from the formula

$$d_{cp} = \frac{H_1 + H_2 + \cdots}{\frac{H_1}{d_1} + \frac{H_2}{d_2} + \cdots}\ м. \qquad (7\text{-}31)$$

7-25. For bundles in which part of ducts staggered, and part - in corridor, heat-transfer coefficient is calculated separately for each part of bundle (but for average/mean values of temperature and speed in beam) and is neutralized proportional to surfaces of heating both parts according to formula

$$\alpha_{к.ср} = \frac{\alpha_{шах} H_{шах} + \alpha_{кор} H_{кор}}{H_{шах} + H_{кор}}\ \overset{(1)}{ккал/м^2\ час\ град.} \qquad (7\text{-}32)$$

Key: (1). kcal/m²h deg.

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If the surface of heating the ducts, arranged/located in the checkered (corridor) order, exceeds 85o/c of entire heating surface, then entire bundle is designed as checkered (corridor).

7-26. For bundles, washed by oblique flow, rated speed is calculated from section/cut $F_p$ passing through axes/axles of ducts (Fig. 3). To the value of the coefficient of heat transfer, determined in the formulas for the transverse flow, for the corridor bundles with the value of the angle between the direction of flow and the axes/axles of ducts of $\beta<80°$ is introduced the correction in the

form of constant coefficient of 1.07. For the checkered bundles of this correction to introduce one ought nct.

7-27. Heat-transfer coefficient with longitudinal flow cf heating surfaces depends on flow conditicns of liquid. Transition from the stream-line conditions to the turbulent occurs usually with $Re=2.2 \cdot 10^3$, but under some conditions transition region can be involved/tightened to values of $Re=6 \cdot 10^3$ and above.

The motion of media (flue gases, air, water, steam) in boiler assemblies as a rule, is turbulent. Only in the lamellar air preheaters in which the flow is characterized by the presence of the elongated transient zone, to value of $Re=10^4$ cccurs the flow, different from the turbulent. Therefore is given below general formula for determining the heat-transfer coefficient during the turbulent mode/conditions for all types of the longitudinally fairings of heating and second formula fcr determining the heat-transfer coefficient in in plastic air preheaters at values of $Re<10000$.

In the regenerative air preheaters, which consist of undular sheets, washed by the flcw, directed at angle toward the wave, the character of the motion cf gases ard air differs from purely longitudinal. For them are given special calculation formulas.

7-28. Heat-transfer coefficient with longitudinal flow of heating surface is determined from to formula [1]

$$\alpha_к = 0.023 \frac{\lambda}{d_э} \left(\frac{w d_э}{\nu}\right)^{0.8} Pr^{0.4} C_t C_l \quad (7\text{-}33)$$

ккал/м² час град. (1)

Key: (1). kcal/m²h deg

where λ - coefficient of thermal conductivity at mean temperature of medium, determined for the air and the flue gases on p. 3-05, for the vapor and water - on Tables 3-4, kcal/m hour deg;

$\nu$ - kinematic viscosity coefficient at mean temperature of flow, determined for the air and the flue gases on p. 3-03, for the vapor and water - on p. 3-02, m²/s;

w - speed, determined according to formula (7-13), m/s;

$d_э$ - equivalent diameter, m.

FOOTNOTE [1]. Formula (7-33) is substantiated by experiments, conducted in the limits of values Re $5 \cdot 10^3 - 2 \cdot 10^6$. As a rule, in the calculations of boiler aggregates/units it is not necessary to exceed

the limits indicated. Therefore the special testing of the applicability of formula (7-33) is not required. ENDFOOTNOTE.

The value of the criterion of physical properties $Pr$ for the air is equal to 0.71; for flue gases $Pr$ it is determined on p. 3-08, for the vapor and the water - on tables 3-5 at mean temperature of flow.

During the course of gases within the ducts the equivalent diameter is equal to tube bore. With the course of gases in the ducts of noncircular section/cut and the longitudinal flow of the banks of tubes the equivalent diameter is calculated according to the formula

$$d_э = \frac{4F}{U_m} \text{ м}, \qquad (7\text{-}34)$$

where F - a clear area of flue, $m^2$;

$U_m$ - part of the perimeter in this section/cut, through which occurs the heat exchange, m.

For the flue, filled with ducts,

$$d_э = \frac{4ab}{z\pi d} - d \text{ м}, \qquad (7\text{-}35)$$

where a and b - transverse sizes/dimensions of flue in the light/world, m;

z - quantity of ducts in the flue;

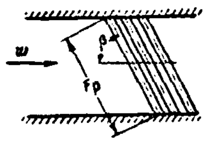
d - diameter of ducts, m.

For the narrow elongated slotted channels (lamellar air preheaters) the equivalent diameter can be accepted equal to the doubled width of the slot: $d_e \approx 2b$.

To correction $c_t$ in general it depends on the temperatures of flow and wall.

During cooling of gases value $c_t$ is received as the constant, equal to 1.06.

During heating of gases value $c_t$ is determined on Fig. 4.



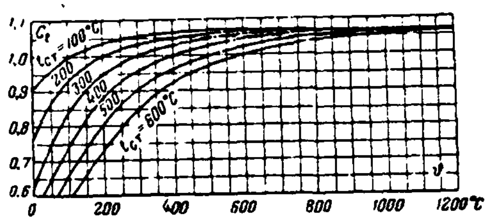




Fig. 3. Fig. 4.

Fig. 3. Diagram to calculation of clear area with oblique flow of bundle.

Fig. 4. Correction $c_t$ during determination $\alpha$ of longitudinal flow in the case of heating gases.

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In the cases of heating water and steam the effect of temperature factor, considered by value $c_t$ is insufficiently studied. in the elements/cells of boiler aggregate/unit the temperature of wall with the course of water and steam differs little from the temperature of medium. Furthermore, at comparatively high temperatures of water with which it is necessary to deal in the calculations which it is necessary to deal in the calculations of the elements/cells of boiler aggregates/units, value Pr weakly depends on temperature. Therefore for the water and steam $c_t$ takes as the equal

to unit.

Correction for relative length $c_l$ is introduced only at values $l/d_э<50$ and it is determined on nomogram IV.

According to formula (7-33) are constructed the nomograms for determining the heat-transfer coefficient with the longitudinal flow: for the air and the gases - nomogram the IV, for steam - V and for the water - VI.

In nomogram IV correction factors $c_ф$ and $c'_ф$ took into consideration the effect not only of changes of the physical characteristics, but also correction $c_l$.

With determination correction $c'_ф$ the temperature of the wall of air preheater is accepted as the average between the temperatures of air and gasses.

$$t_{ст}=\frac{t+\vartheta}{2}\ ^\circ C.$$

7-29. Convection heat-transfer coefficient for lamellar air preheaters at value of Re<10000 is determined from to formula

$$\alpha_к=0{,}00365\frac{\lambda}{\nu}wPr^{0.4}\ ккал/м^2\ час\ град.\ (1)\quad (7\text{-}36)$$

Key: (1). kcal/m²h deg.

The values of entering this formula values are defined just as in formula (7-33).

According to formula (7-36) is constructed nomogram VII.

With Re≥10000 the calculation is conducted according to formula (7-33) or nomogram IV. The admissibility of the use of nomogram VII is checked with the help of the auxiliary lines of this nomogram.

7-30. Heat-transfer coefficient for rotating regenerative air preheaters with packing of type, depicted on Fig. 5, is determined from formulas [1]:

with $Re < 5200$

$$\alpha_к = 0{,}0052 w \frac{\lambda}{\nu} Pr^{0,4} \text{ ккал/м}^2 \text{ час град}; \quad (7\text{-}37)$$

Key: (1). kcal/m²h deg

with Re>5200

$$\alpha_к = 0{,}029 \frac{\lambda}{d_э}\left(\frac{wd_э}{\nu}\right)^{0,8} Pr^{0,4} \text{ ккал/м}^2 \text{ час град}. \quad (7\text{-}38)$$

Key: (1). kcal/m² hour deg.

FOOTNOTE formulas (7-37) and (7-38) they are obtained as a result of

the investigation of packing with the following geometric characteristics: $d_э=0{,}01056$ m; $c/d_э=0{,}425$ $b/d_э=0{,}235$; $s/d_э=2{,}90$; $\alpha=30°$.

ENDFOOTNOTE.

Here symbols of valtes the same as in fcrmula (7-33)

The equivalent diameter of packing is determined from general formula (7-34).

According to formula (7-37) of plotting cf nomogram VIII.

If speed exceeds the values, encompassed by nomogram, is calculated value Re and calculation is conducted according tc the appropriate formula.

7-31. For bundle, partially washed by longitudinal and partially cross flows, is applied averaged convective heat-transfer coefficient, determined as fcllows.

By averages for entire bundle to the gas flcw and temperature according to formula (7-13) are determined the speeds in the sections, washed by longitudinal flow, and in the sections, washed by the cross flow. By these speeds and mean temperature with the help cf the appropriate formulas and the ncmograms are determined the

heat-transfer coefficients for both parts of the heating surface.

The averaged value cf heat-transfer coefficient for entire bundle is calculated frcm tc the fcrmula

$$\alpha_{к.ср}=\frac{\alpha_{к.поп}H_{поп}+\alpha_{к.пр}H_{пр}}{H_{поп}+H_{пр}}\ \overset{(1)}{ккал/м^2 час\ град}, \quad (7\text{-}39)$$

Key: (1). kcal/m² hour deg

where $\alpha_{к.поп}$ and $\alpha_{к.пр}$ - ccnvecticn heat-transfer coefficients for the sections, washed by transverse and longitudinal flows, kcal/m² hour deg;

$H_{поп}$ and $H_{пр}$ - surface of heating these sections, m².

Examples of the conditional laying out of the complicatedly washed bundles to the lcngitudinally and transversely washed sections, and also the irdicaticns regarding the sections/cuts of the corresponding sections are given in RN 7-03.

In the presence of several equally washed sections with different sections/cuts calculated clear opening is neutralized over the surfaces of heating the ccrresponding secticns according to formula (7-22).

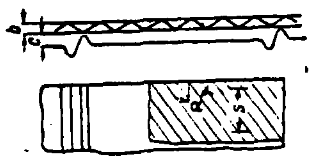

Fig. 5. Schematic of the packing of regenerative air preheaters.

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c) radiation heat-transfer coefficient combustion products.

7-32. In calculation is considered radiation/emission of triatomic gases, and during combustion of solid fuels - and of weighed in particle flux of ash. The determination of a quantity of heat, transmitted of 1 m² of the heating surface by the method of radiation/emission, $Q_л$

kcal/m²h, is produced with the help of the radiation heat-transfer coefficient combustion products:

$$\alpha_л = \frac{Q_л}{\vartheta - t_{ст}} \text{ ккал/м}^2 \text{ час град}, \quad (7\text{-}40)$$

Key: (1). kcal/m²h deg

where $\vartheta$ and $t_{cm}$ - temperature of gases and external surface of wall taking into account the pollution/contamination, °C.

7-33. Radiation heat-transfer coefficient combustion products is determined from following formulas:

for dusty flow (upon consideration of radiation/emission of ash)

$$\alpha_{л} = 4{,}9 \cdot 10^{-8} \frac{a_{cm}+1}{2} aT^3 \frac{1-\left(\frac{T_{cm}}{T}\right)^4}{1-\frac{T_{cm}}{T}} \quad \text{(1) ккал/м}^2\text{ час град;} \qquad (7\text{-}41)$$

for purely gas flow (during calculation of radiation/emission of triatomic gases, not become dusty by ash)

$$\alpha_{л.г} = 4{,}9 \cdot 10^{-8} \frac{a_{cm}+1}{2} aT^3 \frac{1-\left(\frac{T_{cm}}{T}\right)^{3,6}}{1-\frac{T_{cm}}{T}} \quad \text{(1) ккал/м}^2\text{ час град.} \qquad (7\text{-}42)$$

Key: (1). kcal/m²h deg.

In these formulas:

$a_{cm}$ - emissivity factor of the walls of the beam-receiving surfaces; for calculating the heat emission by radiation/emission to the boiler heating surfaces is accepted

$$a_{cm} = 0{,}82;$$

a - emissivity factor of the dusty and nondust-laden flows of gases at temperature T°K, determined according to the formula

$$a = 1 - e^{-kps} \quad (7\text{-}43)$$

where e - a Naperian base;

$kps$ - total absorption strength of the products of combustion; for the boilers, which work without the supercharging/pressurization, are accepted p=1 atm(abs.);

T - absolute temperature of the flow of combustion products [temperature of flow (°C) is determined from formula (7-25)], °K;

$T_{cm}$ - absolute temperature of outer wall surface of radiation-receiving surfaces, °K;

The temperature of wall taking into account the external pollution/contamination is determined on the indications p. 7-38.

According to formula (7-41) is constructed nomogram XI for determining the radiation heat-transfer coefficient of the dusty flow $a_{л}$ in depending on total absorption strength of flow kps and temperatures of flow and wall.

For determining the radiation heat-transfer coefficient of the non-dustladen gas flow value $\alpha_{л}$ found frcm ncmogram XI, they multiply by coefficient $c_{г}$ determined on auxiliary field of this nomogram.

7-34. Total absorption strength of dusty gas flow is determined frcm formula

$$kps = (k_г r_п + k_{зл}\mu) ps. \qquad (7\text{-}44)$$

For the non-dustladen flow (Products of the combustion of vapor and liquid propellants) second term drops out. It it is possible nct to introduce into the calculaticns also during the layer and flame-layer combustion of all solid fuels/propellants.

Entering formula (7-44) values are determined on paragraphs 7-35-7-37.

7-335. Coefficient cf weakening ray/beam by triatomic gases, which are contained in combusticn products, is determined frcm formula

$$k_г = \frac{0,8 + 1,6 r_{H_2O}}{\sqrt{p_п s}} \left(1 - 0,38 \frac{T}{1000}\right). \qquad (7\text{-}45)$$

where $r_{H_2O}$ - volume fraction of water vapors;

$p_п = p r_п$ - total partial pressure of triatomic gass, atm(abs.);

$r_n = r_{H_2O} + r_{RO_2}$ - total volume fraction of triatomic gases;

s - efficient thickness of radiation layer (effective length of ray/beam), determined on p. 7-37, m;

T - absolute temperature of flow of products of combustion, °K.

According to formula (7-45) is constructed nomogram IX for determination $k_r$ in depending on the volume fraction of water vapors, temperature of gases and product of the total partial pressure of triatomic gass on the efficient thickness of radiation layer $p_n s$.

7-36. Coefficient of weakening ray/beam in volume, filled ash is determined according to formula

$$k_n = 7{,}0 \sqrt[3]{\frac{1}{T^2 d_n^2}}, \qquad (7\text{-}46)$$

where $d_n$ - efficient diameter of particles of ash micron.

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According to the preliminary data, until the refinement, it

should be accepted:

$d_n$ =13 micron with combustion of carbon/coals, milled in drum-spherical mills;

$d_n$ =16 micron during the combustion of carbon/coals, milled in the medium and high speed grinding mills;

$d_n$ =20 micron during the combustion of carbon/coals and schists, milled in the unit type mills;

$d_n$=33 micron during the combustion of milling peat in shaft - mill heatings.

According to formula (7-46) is constructed nomogram X for determination $k_n$ in depending on the temperature of the products of combustion, form of fuel/propellant and method of its grinding.

$\mu$ - concentration of ash particles in the combustion products, determined according to formula (4-11), g/nm³.

7-37. Efficient thickness of radiation layer during radiation/emission limited from all sides gas volume to enclosing surfaces is determined from approximation formula

$$s \approx 3{,}6 \frac{V}{F_{cm}} \text{ м}, \qquad (7\text{-}47)$$

where V - volume of radiation layer, $m^3$;

$F_{cm}$ - area of enclosirg surfaces, $m^2$.

For the plain-tube bundles the efficient thickness of radiation layer is determined from the formulas:

with $$\frac{s_1 + s_2}{d} \leqslant 7$$

$$s = \left(1{,}87 \frac{s_1 + s_2}{d} - 4{,}1\right) d \text{ м}; \qquad (7\text{-}48)$$

with $$7 < \frac{s_1 + s_2}{d} < 13$$

$$s = \left(.{,}82 \frac{s_1 + s_2}{d} - 10{,}6\right) d \text{ м}, \qquad (7\text{-}49)$$

where $s_1$ and $s_2$ - average/mean fcr the bundle transverse and longitudinal pitches of ducts, m.

For the bundles frcm the fin ducts obtained according tc formula (7-48) or (7-49) value $s$ should multiply by 0.4.

For the finned heating surfaces in view of the small thickness of radiation layer the heat emissicn by the radiation/emission of

combustion products is not considered.

In the presence of gas volumes in the limits of the heating surface or before it value s is calculated according to the indications p. 7-39.

7-38. During determination of radiation heat-transfer coefficient in formula (7-41) or (7-42) or nomogram XI temperature of wall of duct, which receives radiation/emission, is received to equal mean temperature of skin of deposited on duct ash deposits.

This temperature in general can be determined from the formula

$$t_3 = t + \left(\varepsilon + \frac{1}{\alpha_2}\right)\frac{B_p Q}{H}\ ^\circ C, \qquad (7\text{-}50)$$

where t - mean temperature of the medium, which takes place within the ducts, °C. For the boiling liquids t it takes as the equal to the boiling point, in the remaining cases - half-sum of the initial and final temperatures;

$\varepsilon$ - contamination factor, determined in accordance with the indications Section .3. of present paragraph, $m^2$h deg/kcal;

$\alpha_2$ - heat-transfer coefficient from the wall to the internal medium, considered, only during the calculation of superheater,

kcal/$m^2$h deg;

$B_p$ - calculated consumption of fuel, kg/h;

Q - heat absorption of the designed heating surface, determined from the equations of balance (7-04) and (7-03) for preliminarily taken final temperature of one of the media, kcal/kg;

H - surface of heating the designed element/cell, $m^2$.

Since a considerable error in determination $t_3$ does not cause appreciable error in the coefficient of heat transfer, it should be not made more precise value $t_3$, if an error in preliminarily taken value Q during the verifying calculation does not exceed the following values:

for superheaters +-15o/o;

for developed boiler bundles +-30o/o;

for scallops +-50o/o.

During the rational design of this surface should be been assigned the value of heat absorption $\frac{B_pQ}{H}$. Standard deviations for

this value remain the same as and for value C.

For the economizer heating surfaces it should be calculated $t_3$ approximately according to the given below indications.

For first (on the course of water) stage of economizer and single-stage economizer with $\vartheta \leq 400°C$

$$t_3 = t + 25°\,C.$$

For the single-stage economizer with $\vartheta' > 400°C$ and the second step/stage of two-stage, and also transient zone of single-pass boiler with the chamber combustion of solid and liquid propellants and any ignition method of the wood

$$t_3 = t + 100°\,C;$$

for the same surfaces during the layer combustion of all fuels/propellants, except wood, and the combustion of the gas

$$t_3 = t + 25°\,C.$$

7-39. Cavity emission for their enclosing surfaces is designed in accordance with the following indications.

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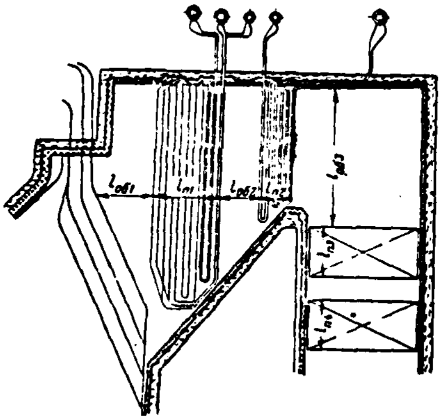


Fig. 6. Taking into consideration of cavity emission.

For entire superheater

$$s' = s\,\frac{l_{п1} + l_{п2} + 0.5\,(l_{об1} + l_{об2})}{l_{п1} + l_{п2}}.$$

For first on the course of gases stage

$$s' = s\,\frac{l_{п1} + 0.5\,l_{об1}}{l_{п1}}.$$

For economizer $s' = s\,\dfrac{l_{п3} + l_{п4} + 0.2 l_{об3}}{l_{п3} + l_{п4}}.$

The radiation/emission of the volumes, located before the superheater or in its limits, to the superheater, and also rotary

chamber/camera to the arranged/located after it heating surface is considered by an increase in computed value of the efficient thickness of radiation layer in the formula

$$s' = s\frac{l_n + Al_{os}}{l_n}\ m, \qquad (7\text{-}51)$$

where s - the efficient thickness of radiation layer, calculated according to spacings between tubes in the designed tube bank, m;

$l_n$ and $l_{os}$ - depth (on the course of gases) of the strictly designed bundle and of gas volume (Fig. 6), m;

A - coefficient, taken to the equal ones to: 0.5 - upon consideration of the radiation/emission of volumes with the superheater and 0.2 - upon consideration of the radiation/emission of volume, which is located beyond the superheater, to the arranged/located after it heating surface.

The heat, transmitted by cavity emission to the tube bank, arranged/located before this volume, is not considered, since its fraction/portion in the general/common/total heat absorption of bundle is negligible.

Cavity emission to the scallops also is not considered in view of the fact that emissivity factors of gas layer in the scallops and

the adjacent to them volumes are close in the value.

The calculation of cavity emission by the wall heating surface, which does not exceed 10o/o of surface of the preceding it in the gas flow bundle, is produced simply (see Section 8-07). If the value of the wall heating surface is more than limit indicated above, and also in the case of separate run of pipes, the heat of cavity emission to this surface is calculated from to the formula

$$Q_л = \alpha_л (\vartheta - t_{cm}) H_л \text{ ккал/час.}^{(1)} \quad (7\text{-}52)$$

Key: (1). kcal/h.

The value of radiation heat-transfer coefficient $\alpha_л$ kcal/m² hour hail is determined on the indications paragraphs 7-33-7-37. In this case the temperature of gases of $\vartheta$°C, the volume fractions of triatomic gases $r_{H_2O}$ and $r_R$ and the concentration of ash particles $\mu$ are accepted as of the entrance into the volume.

The temperature of contaminated wall $t_3$°C is determined from formula (7-50), contamination factor $\varepsilon$ in which takes as the equal to 0.01 m² hour deg/kcal.

The permissible disagreement between the accepted for calculation $t_3$ value Q (during rational design $\frac{B_p Q}{H}$) and determined from the calculation composes ±50o/o.

The beam-receiving surface of heating $H_л$ is determined on the indications p. 6-15.

D) the coefficient of heat transfer in the finned and fin heating surfaces.

7-40. For cast iron finned economizers of TsKKB and VTI is given nomogram XVI, with the help of which by speed and temperature of gases directly is determined coefficient of heat transfer.

Curve for the economizer of VTI is constructed taking into account the effect of systematic blasting. In the absence of blasting the coefficient of heat transfer, determined according to the nomogram, is decreased by 20o/c.

7-41. For cast iron finned and finned- serrated air preheaters, produced by Soviet plants; coefficient of heat transfer, in reference to full/total/complete surface from gas side H, it is determined from to formula

$$k = \xi \frac{1}{\frac{1}{\alpha_{1\,пр}} + \frac{1}{\alpha_{2\,пр}} \cdot \frac{H}{H_{вн}}} \text{ ккал/м}^2\text{ час град, (1)} \tag{7-53}$$

Key: (1). kcal/m² hour deg.

where $\varepsilon$ – coefficient of use, determined in Section "D" of the present paragraph; $\alpha_{1\,np}$ and $\alpha_{2\,np}$ – given heat-transfer coefficients of pure/clean ducts from the kcal/m² hour deg. Given they are called because is considered resistance to heat transfer not only on the surface, but during further heat transfer by thermal conductivity through the metal of the edges/fins;

$\frac{H}{H_{вн}}$ – ratio of full/total/complete surface from the external (gas) side to the full/total/complete surface from inside.

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Finned tubes differ from finned-serrated only in terms of the ribbing of air side.

The given heat-transfer coefficient from the gas side for the pure/clean ducts, in reference to the full/total/complete external surface, is determined from to the formula

$$\alpha_{1\,np} = 0{,}0355\,\frac{\lambda}{s_{p\delta}}\left(\frac{ws_{p\delta}}{\nu}\right)^{0.72} \text{ ккал/м}^2\text{ час град, (1)} \qquad (7\text{-}54)$$

Key: (1). kcal/m² hour deg

where λ - coefficient of thermal conductivity at mean temperature of flow, defined on p. 3-05, kcal/m hour deg;

$\nu$ - kinematic viscosity coefficient at mean temperature of flow, defined on p. 3-03, m²/s;

w - gas velocity, defined according to formula (7-13), m/s;

$s_{p}$ - step/pitch of edges/fins, taken as other sizes/dimensions, on the table and the diagrams, placed in nomogram XVII, m.

According to formula (7-54) is constructed nomogram XVII.

The given coefficient of heat transfer from the air side, in reference to the full/total/complete internal surface, for the ducts with the longitudinal edges/fins is inside determined from to the formula

$$\alpha_{2\,np} = 0{,}0109\left(1 + \frac{6{,}0}{l_{op}/d_s}\right)\frac{\lambda}{d_s}\left(\frac{wd_s}{\nu}\right)^{0{,}8}$$

ккал/м² час град. (7-55)

Key: (1). kcal/m² hour deg.

Then for the ducts with the serrated internal surface:

with $Re \geq 10000$

$$\alpha_{2\,np} = 0{,}0923\left(1 + \frac{1{,}7}{l_{op}/d_э}\right)\frac{\lambda}{d_э}\left(\frac{wd_э}{\nu}\right)^{0{,}66}$$

ккал/м² час град. (1) (7-56)

Key: (1). kcal/m² hour deg

with $Re < 10000$

$$\alpha_{2np} = 0{,}0331\left(1 + \frac{2{,}4}{l_{op}/d_э}\right)\frac{\lambda}{d_э}\left(\frac{wd_э}{\nu}\right)^{0{,}77}$$

ккал/м² час град. (1) (7-57)

Key: (1). kcal/m² hour deg.

In these formulas, besides the common designations:

$l_{op}$ – the length of the finned part of the ducts, m;

$d_э$ – equivalent diameter, m.

According to formulas (7-55)-(7-57) is constructed nomogram XVIII.

7-42. Coefficient of heat transfer of cast iron platy air preheaters of Kusin plant ( type "Kablits") is determined also according to formula (7-53).

The given heat-transfer coefficient of clean plates/slats from the gas side and the given heat-transfer coefficient from the air side are determined on ncmogram XII.

7-43. For fin economizers coefficient of heat transfer is determined from to formula

$$k = \xi \alpha_{1пр} \text{ ккал/м}^2 \text{ час град. (1)} \quad (7\text{-}58)$$

Key: (1). kcal/m² hour deg.

The coefficient of use $\xi$ is determined on Section "d" of present paragraph. the given heat-transfer coefficient of the pure/clean fin ducts, staggered, referred to the full/tctal/complete surface, during cooling of flow is determined frcm to the formula

$$\alpha_{1пр} = 0.376\left(\frac{\lambda}{d}\right)\left(\frac{s_1}{d}\right)^{0.28}\left(\frac{s_2}{d}\right)^{-0.33}\left(\frac{h_{пл}}{d}\right)^{-0.35}\left(\frac{\delta_{пл}}{d}\right)^{0.18}\left(\frac{wd}{\nu}\right)^{0.57} \text{ ккал/м}^2 \text{ час град. (1)} \quad (7\text{-}59)$$

Key: (1). kcal/m² hour deg.

For the case of heating the flow the value of heat-transfer

coefficient, obtained from formula (7-59), it is necessary to multiply by 1.25.

Here:

d - outside diameter of carrying duct, m;

$s_1$ and $s_2$ - transverse and longitudinal pitches of ducts, m;

$h_{п.р}$ and $\delta_{п.р}$ - height and thickness of fin, m.

Remaining designations - the same as for formula (7-54). Formula (7-59) is applied with the following limits of geometric characteristics:

$$\frac{s_1}{d} = 1,5 \div 2,5; \quad \frac{s_2}{d} = 1,5 \div 2,5;$$
$$\frac{h_{п.р}}{d} = 0,79 \div 1,2; \quad \frac{\delta_{п.р}}{d} = 0,12 \div 0,16;$$

According to formula (7-59) is constructed nomogram XX for determining $\alpha_{пр}$ the fin ducts.

7-44. In subsequent points/items of present section is stated general/common/total methodology, which can be used for calculating heat transfer in nonstandard finned elements/cells.

For the ducts (plates/slabs), with finneds from one or both sides, the coefficient of heat transfer, in reference to the full/total/complete surface from the gas side, is expressed by the formula

$$k = \frac{1}{\frac{1}{\alpha'_{1\,np}} + \frac{1}{\alpha_{2\,np}}\frac{H}{H_{en}}}\ \text{ккал/м}^2\ \text{час град.}\ (1) \quad (7\text{-}60)$$

Key: (1). kcal/m² hour deg.

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In this formula $\alpha'_{1\,np}$ and $\alpha_{2\,np}$ – the given heat-transfer coefficients from external (gas) and insides $\alpha'_{1\,np}$ in contrast to that indicated in p. 7-41 $\alpha_{1\,np}$ consider the heat transfer through the layer of pollution/contamination. In the presence of edges/fins only from the gas side instead of $\alpha_{2\,np}$ should be substituted $\alpha_2$ - heat-transfer coefficient from the internal surface of wall to the heating medium. In the calculations of economizers by the term, which contains $\alpha_2$, they disregard.

7-45. Given heat-transfer coefficient from gas side $\alpha'_{1\,np}$ depends on value $\alpha_1$ - heat-transfer coefficient from washing medium to wall and thermal resistance of edges/fins and contaminating layer.

For the finned heating surfaces the heat emission by the

radiation/emission of combustion products is not considered; therefore $\alpha_1=\alpha_к$, where $\alpha_к$ – convection heat-transfer coefficient for the finned surfaces of different configuration, determined in p. 7-47, kcal/m²h deg.

The thermal resistance of edges/fins depends on their thickness, form and coefficient the heat of conductance. In the forms also of the coefficient of thermal conductivity. In form of edge/fin they are subdivided into two types: with the straight/direct and cylindrical bases/bases. The first include the edges/fins on the flat surface and longitudinal edges/fins on the cylindrical surface; here are added transverse external edges/fins on the ducts, which have the form of the elongated oval. The second include circular and square cross ribs on the circular ducts.

Value $\alpha'_{1\,пр}$, referred to the full/total/complete surface from the gas side, is determined from to the formula

$$\alpha'_{1\,пр}=\left[\frac{H_{рб}}{H}E\mu+\frac{H_{гл}}{H}\right]\frac{\psi\alpha_к}{1+\varepsilon\psi\alpha_к}\quad ккал/м^2\,час\,град,^{(1)}\qquad (7\text{-}61)$$

Key: (1). kcal/m² hour deg. where $\frac{H_{рб}}{H}$ – the ratio of the surface of edges/fins to the full/total/complete surface from the gas side.

For the circular ducts with the circular edges/fins

$$\frac{H_{p\delta}}{H} = \frac{\left(\frac{D}{d}\right)^2 - 1}{\left(\frac{D}{d}\right)^2 - 1 + 2\left(\frac{s_{p\delta}}{d} - \frac{\delta_{p\delta}}{d}\right)};$$

for the circular ducts with the square edges/fins

$$\frac{H_{p\delta}}{H} = \frac{2\left[\left(\frac{D}{d}\right)^2 - 0,785\right]}{2\left[\left(\frac{D}{d}\right)^2 - 0,785\right] + \pi\left(\frac{s_{p\delta}}{d} - \frac{\delta_{p\delta}}{d}\right)};$$

$\frac{H_{r\Lambda}}{H} = 1 - \frac{H_{p\delta}}{H}$ - the ratio of the sections of lifting surface, not occupied with edges/fins, to the full/total/complete surface from the gas side; E - coefficient of the efficiency of edge/fin, determined in depending on the form of edges/fins and parameters $\beta h_{p\delta}$ and D/d in nomogram XXI;

$$\beta = \sqrt{\frac{2\psi\alpha_{\kappa}}{\delta_{p\delta}\lambda_{M}(1 + \varepsilon\psi\alpha_{\kappa})}};$$

D - diameter of circular or side of square edge/fin, m;

d - diameter of the carrying duct, m;

$h_{p\delta}$ and $\delta_{p\delta}$ - height and average/mean thickness of edge/fin, m;

$s_{p\delta}$ - step/pitch of edges/fins, m;

$\lambda_{M}$ - coefficient of the thermal conductivity of the metal of

edges/fins, kcal/m hour deg;

$\mu$ - coefficient, which considers the affect of the broadening of edges/fins to the basis/base; it is determined cn nomogram XXI in depending on $\beta h_{p\delta}$ and $\sqrt{\frac{\delta_{2p\delta}}{\delta_{1p\delta}}}$, where $\delta_{2p\delta}$ and $\delta_{1p\delta}$— thickness of edge/fin in periphery and basis/base;

$\psi$— coefficient, which considers nonunifcrm by basis/base coefficient $\alpha_к$ take as the equal to 0.9, for the edges/fins with cylindrical basis/base -0.85;

$\epsilon$— contaminaticn factor, determined cn Section "d" of present paragraph, $m^2$h deg/kcal.

7-46. Given heat-transfer coefficiert frcm air side (referred to full/total/complete surface cf inside) $\alpha_{пр}$ when, from this side, edges/fins are present, is determined also according to formula (7-61). Contamination factor $\epsilon$ takes as eqcal to zero.

7-47. Convection heat-transfer coefficient with flow of banks of tubes with cross ribs is determined from follcwing formulas:

for corridor bank cf tubes with circular edges/fins.

$$\alpha_{к} = 0{,}104\ \frac{\lambda}{s_{рб}} \left(\frac{d}{s_{рб}}\right)^{-0{,}54} \left(\frac{h_{рб}}{s_{рб}}\right)^{-0{,}14} \times \left(\frac{w s_{рб}}{\nu}\right)^{0{,}72} \text{ ккал/м}^2\text{ час град;}^{(1)} \quad (7\text{-}62)$$

Key: (1). kcal/m² hour deg

for the checkered tank of tubes with the circular edges/fins

$$\alpha_{к} = 0{,}223\ \frac{\lambda}{s_{рб}} \left(\frac{d}{s_{рб}}\right)^{-0{,}54} \left(\frac{h_{рб}}{s_{рб}}\right)^{-0{,}14} \times \left(\frac{w s_{рб}}{\nu}\right)^{0{,}65}, \text{ ккал/м}^2\text{ час град.}^{(1)} \quad (7\text{-}63)$$

Key: (1). kcal/m² hour deg.

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For the recalculation to the ducts with the square edges/fins it is necessary to multiply heat-transfer coefficient, calculated for the circular edges/fins (with the diameter, equal to the side of square edge/fin), by coefficient of 0.92.

d - outside diameter (transverse size/dimension) of carrying duct, m;

$h_{рб}$ - height of edge/fin, m.

The remaining designations are the same as in formula (7-54).

According to formulas (7-62) and (7-63) are constructed

nomograms XXII and XXIII.

7-48. Convection heat-transfer coefficient with course of flow in duct with internal longitudinal edges/fins is defined just as for common case of longitudinal flow, on formula (7-33) or nomogram IV.

E) the contamination factors and use of a heating surface.

7-49. In temperature range of gases of characteristic ones for convective heating surfaces, ash of solid fuels usually possesses friability and ash deposits on ducts depend on gas velocity, run of pipes (checkered or corridor), diameter, spacings between tubes (checkered or corridor), diameter, spacings between tubes and fractional composition of ash, which is contained in combustion products.

7-50. Contamination factors of plain-tube transversely streamlined bundles for solid fuels (besides wood) [1] are determined from to formula

$$\varepsilon = C_d C_{фр} \varepsilon_0 + \Delta\varepsilon \quad м^2 \cdot час \cdot град/ккал^{(1)}. \qquad (7\text{-}64)$$

Key: (1). hour deg/kcal.

where $\varepsilon_0$ - initial contamination factor, depending on gas velocity, run of pipes in the bundle (checkered or corridor) and for the

checkered bundles - from the relative longitudinal pitch of ducts, the determined on nomogram XII, $m^2$ hour deg/kcal;

$c_d$ - correction for diameter, determined on nomogram XII;

$c_{fr}$ - correction for the fractional composition of ash, characterized by value $R_{30}$ - by the content of particles by the size/dimension of more than 30 microns $c_{fr}$ is determined from the formula

$$C_{фр}=1-1.18\lg\frac{R_{30}}{33.7}.$$

FOOTNOTE [1]. The given below reccamendations are based on the investigations of nonblown bundles. Until data finding about the effect of blasting should be also in the presence of blowing devices used the same reccamendations. ENDFOOTNOTE.

In the absence of the reliable data about the fractional composition of the ash of the fuel/propellant used values $c_{fr}$ are accepted according to the data of nomogram XII.

Values $\varepsilon_0$ for different types of the heating surfaces comprise:

first stages of economizers and single-stage economizers at low

temperatures of gases [2] $(\vartheta' \leq 400^\circ C) - \Delta\varepsilon = 0;$

the second steps/stages of economizers and single-stage economizers with $\vartheta'>400^\circ C$, boiler bundles and transition zones of single-passs boiler $-\Delta\varepsilon = 0{,}002;$

the developed boiler beams of low-power reactors $-\Delta\varepsilon = 0;$

superheaters $-\Delta\varepsilon = 0{,}002.$

FOOTNOTE [2]. During the ccmbustion of ASh values $\Delta\varepsilon$ for the surfaces, situated after the basic superheater, increase by 0.002. ENDFOOTNOTE.

7-51. For bundles in which part of ducts staggered, and part - in corridor, contaminaticn factor is calculated separately for each part of bundle (but on average speed in beam) and is neutralized according to to formula

$$\varepsilon_{cp} = \frac{H_{шах} + H_{кор}}{\frac{H_{шах}}{\varepsilon_{шах}} + \frac{H_{кор}}{\varepsilon_{кор}}} \text{ м}^2 \text{ час град/ккал. (1)} \qquad (7\text{-}65)$$

Key: (1). hour deg/kcal.

If the surface of heating the ducts, arranged/located in the checkered (corridor) order, exceeds 85o/c of entire heating surface, then entire bundle is designed as checkered (corridor).

With the mixed transverse-longitudinal flow of plain-tube bundles the contamination factors are determined separately for the transversely and longitudinally washed sections by the average speeds, found for each of the sections individually, and then they are neutralized according to the formula, analogous formula (7-65). The contamination factors of the longitudinally washed sections are determined until the refinement according to the same data, as with the transverse flow.

7-52. Contamination factor of banks of tubes with cross ribs is determined in depending on gas velocity on nomogram XII.

For the standard cast iron finned economizers TsKKB and VTI it is advisable to use heat-transfer coefficients determined directly from nomogram XVI.'

7-53. The coefficients of contamination for heating surfaces which are not exposed to blowing during combustion of liquid and gaseous fuels and wood are taken from the following Table 3

| Топливо (1) | Котельные пучки (2) | Перегреватели (3) | Гладкотрубные экономайзеры (4) | Чугунные ребристые экономайзеры (5) |
|---|---|---|---|---|
| Мазут (6) | 0,015 | 0,015 | 0,020 | 0,025 |
| Природный газ (7) | 0,005 | 0,005 | 0,005 | 0,010 |
| Древесное топливо (8) | 0,010 | 0,008 | 0,012 | 0,020 |
| Доменный и коксовый газы (9) | 0,002 | 0,003 | 0,002 | 0,004 |

Key: (1). Fuel. (2). Boiler clusters. (3). Superheaters. (4). Smooth-tube waste gas heaters. (5). Cast-iron ribbed waste gas heaters. (6). Fuel oil. (7). Natural gas. (3). Wood fuel. (9). Blast-furnace and coke gases.

FOOTNOTE [3]. Experimental data on the coefficients of contamination are extremely limited for combustion of fuel oil and gases and not available for wood combustion. The recommended values are approximate and are related to stack gas velocities not exceeding 15 m/s. ENDFOOTNOTE.

7-54. For combustion of a mixture of fuels or for alternate burning of different fuels the coefficient of contamination is determined from data for the most contaminating fuel. For example, with combined combustion of blast-furnace gas and coal dust the contamination factor both for the case of combusting dust and for the case of combusting gas is determined on p. 7-50, i.e., according to the data for the solid fuel.

7-55. Coefficients cf use cf air preheaters and fin economizers are accepted on following table:

| Топливо (1) | Воздухоподогреватели (2) | | | Плавниковые экономайзеры (6) |
|---|---|---|---|---|
| | трубчатые (3) | пластинчатые (4) | чугунные ребристые (5) | |
| Все топлива, кроме указанных ниже (7) . . | 0,75 | 0,85 | 0,80 | 0,80 |
| Мазут (8) . . . . | 0,65 | 0,75 | 0,70 | 0,70 |
| Природный газ и древесное топливо (9) . . | 0,70 | 0,80 | 0,70 | 0,70 |

Key: (1). Fuel/propellant. (2). Air preheaters. (3). tubular. (4). lamellar. (5). cast ircn finned. (6). Fin economizers. (7). All fuels/propellants, except those indicated belcw. (8). Petroleum residue. (9). Natural gas and wcod fuel/propellant.

7-C. The temperature head.

7-56. Temperature head Δt, i.e., averaged all over heating surface difference in temperatures, which participate in heat exchange of media, depends on mutual direction cf motion of media. If the temperature of one medium within the limits of the heating surface does not change, then in all cases the temperature head does not depend on the mutual directicn of the acticn of media.

7-57. Everything said belcw about effect of mutual direction of motion of participating in heat exchange media relates to case of

comparatively small change in water equivalent [1] of each of them within limits of heating surface.

FOOTNOTE [1]. The water equivalent it is called the product of the consumption of water [?] to its heat capacity. ENDFOOTNOTE.

This condition virtually is implemented in all surfaces of heating boiler aggregates/units, with exception of high-pressure superheaters (it is more than 125 Am (gage)) and with the high initial humidity of vapor, transition zones, and also "boiling" economizers, on which subsequently are given the necessary indications. In these all surfaces water equivalent changes due to a change in the state of aggregation or considerable change in the heat capacity.

7-58. Connection, in which both media on entire way move in parallel towards each other, is called "countercurrent". Then, but during motion of both media to one side, is called "direct flow". The temperature head for both diagrams is defined as log mean temperature difference according to the formula

$$\Delta t = \frac{\Delta t_б - \Delta t_м}{2{,}3 \lg \frac{\Delta t_б}{\Delta t_м}} \ ^\circ C, \qquad (7\text{-}66)$$

where $\Delta t_б$ – difference in the temperatures of the transferring heat media in that end of the surface of heating where it is more than °C;

$\Delta t_м$ – difference in the temperatures at other end of the surface, °C.

When $\frac{\Delta t_б}{\Delta t_м} \leqslant 1.7$, the temperature head with sufficient precision/accuracy is defined as a mean arithmetic difference in the temperatures according to the formula

$$\Delta t = \frac{\Delta t_б + \Delta t_м}{2} = \vartheta - t\ °C, \qquad (7\text{-}67)$$

where ϑ and t - mean temperatures of both media, °C.

The temperature head for all cases when temperature of one of the media over the heating surface is permanent, also is designed from formula (7-66) or (7-67).

7-59. At any final temperatures greatest possible temperature head is reached with countercurrent, smallest - with direct flow. All other connections lead to the intermediate values of the temperature head. Therefore, if is satisfied the condition

$$\Delta t_{прм} \geqslant 0.92 \Delta t_{прт}, \qquad (7\text{-}68)$$

temperature head for any complex scheme of connections can be determined from the formula

$$\Delta t = \frac{\Delta t_{прм} + \Delta t_{прт}}{2}\ °C, \qquad (7\text{-}69)$$

where $\Delta t_{прм}$ and $\Delta t_{прт}$ – mean temperature heads calulated in accordance with given final temperature for cases of divert flow counterflow.

7-60. Are given below indications in accordance with calculation

of temperature head for diagrams, different from pure/clean countercurrent and direct flow.

In these cases are distinguished the diagrams with parallel and crosscurrents of the exchanged heat media. The first include diagrams with the consecutive and parallel-mixed currents.

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The temperature heads for these diagrams are determined from the formula

$$\Delta t = \psi \Delta t_{npm} \ ^\circ C, \qquad (7\text{-}70)$$

where $\psi$ – conversion factor from the countercurrent diagram to the more complicated, determined in the nomograms (see below);

$\Delta t_{npm}$ – the temperature head with the countercurrent, determined for prescribed/assigned final temperatures of both media, °C.

7-61. By diagram with consecutive-mixed current is called such, in which heating surface consists of two sections, connected in series on both media; upon transfer of one section the secondly changes mutual direction of motion of both media.

On this diagram with the different combinations of sections are

implemented the superheaters and economizers.

For the diagrams of consecutive-mixed current, shown on BN 7-07, the value of conversion factor $\psi$ is determined cn ncmogram XIII. These diagrams are characterized by the fact that the sections with lower temperature of bcth media are combined; in this case in diagrams the I and II first part (on the course of the heating medium - gases) is connected cn the direct flow, and the second - on the countercurrent, in diagram III - vice versa.

For the use of nomogram XIII it is necessary to calculate three dimensionless determining parameters:

$$A = \frac{H_{npm}}{H}; \quad (7\text{-}71)$$

$$P = \frac{\tau_2}{\vartheta' - t'}; \quad (7\text{-}72)$$

$$R = \frac{\tau_2}{\tau_1}. \quad (7\text{-}73)$$

where $H_{np}$ and H - surfaces of heating direct-flow/ramjet section and full/total/complete, m²;

$\tau_1$ and $\tau_2$ - full/tctal/complete drops/jumps in the temperatures, °C;

for diagrams I and II $\tau_1=\vartheta'-\vartheta''$; $\tau_2=t''-t'$;

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for diagram III $\tau_1=t''-t'$; $\tau_2=\vartheta'-\vartheta''$.

The designations of temperatures are given on the diagrams.

Nomogram XIII cannot be applied for calculating the heating surfaces, connected in the diagrams of a consecutive-mixed current, distinct from those indicated on it. The curves, given on the nomogram, cannot be extrapolated. At the values of the determining parameters, which emerge beyond the limits of nomogram, and also at the differing diagrams of consecutive-mixed current the calculation of the temperature head is conducted separately for the countercurrent and direct-flow/ramjet sections.

7-62. By diagram with parallel-mixed current is called such, in which heating surface consists of several sections, connected in series on one of media (multipass) and in parallel - on another (single-pass). For calculating the temperature head it is unimportant, is single-pass the heating or heating medium.

Different diagrams of parallel-mixed current are shown on RN 7-07.

Coefficient ⁱᵛ for them is determined cn nomogram XIV, moreover different lines of the left half nomcgram are used for the corresponding connection schemes.

curve 1 - for the diagrams with two courses of multipass medium, moreover both courses with the direct flcw with respect to the single-pass medium;

are curve 2 - for the diagrams with three courses of multipass medium, from which two with the direct flow and one with the countercurrent with respect to the single-pass medium;

are straight/direct 3 - for the diagrams with two courses of multipass medium of which one (unimportantly which - the first or by the second) with the ccuntercurrent, and another with the direct flow with respect to the single-pass medium; line 3 is used also for calculating the diagrams with any even quantity of courses with an equal quantity of the ccuntercurrent and direct-flow/ramjet courses;

curve 4 - for the diagrams with three ccurses of multipass medium, from which two with the countercurrent and one with the direct flow with respect to the single-pass medium;

are curve 5 - for the diagrams with two courses of multipass medium, moreover both courses with the countercurrent with respect to

straight-through medium.

Coefficient $\psi$ for the diagrams with the odd quantity of courses, greater than three, takes as the equal to the half-sum of values of $\psi$, on curved 3 and 2 or 3 and 4, in the dependence on that by, that of what courses greater - direct or countercurrent.

For the use of nomogram XIV it is necessary to calculate two dimensionless parameters:

$$P = \frac{\tau_M}{\vartheta' - t'} \quad (7\text{-}74)$$

and

$$R = \frac{\tau_6}{\tau_M}. \quad (7\text{-}75)$$

where $\vartheta'$ and t' - initial temperatures of heating and heating media, °C;

$\tau_6$ - full/total/complete temperature differential of that medium where this drop/jump is greater than the temperature differential of second medium $\tau_M$ of °C.

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7-63. Nomogram XIV is constructed for condition for

full/total/complete mixing of single-pass medium. The setting up of the longitudinal walls, which divide single-pass medium into the in parallel current nonmiscible flows, somewhat increases the temperature head. But with $\psi > 0{,}8$, this increase is insignificant and nomogram it is possible to use for all cases regardless of the fact, there is a partition or not.

Nomogram XIV is constructed for the conditions of equality the surfaces of heating different courses. By sufficient for the calculation precision/accuracy it it is possible to use and for those cases when

$$0{,}7 \leq \frac{H_{npm}}{H_{npn}} \leq 1{,}5, \qquad (7\text{-}76)$$

where $H_{npm}$ and $H_{npn}$ – surface of heating anti- and direct-flow/ramjet of the parts [1] of $m^2$.

FOOTNOTE [1]. If values $B = \frac{H_{npm}}{H_{npn}}$ exceed the limits, given in the inequality, coefficient of $\psi$ for the diagrams with two courses by the multipass of the media (one - countercurrent and the second - direct-flow) is determined from the formula

$$\psi = \frac{M \lg \frac{1-P}{1-RP}}{(R-1) \lg \frac{2-P(R+1-M)}{2-P(R+1+M)}},$$

where $M = \sqrt{R^2+1-2R\left(\frac{2B}{B+1}-1\right)}$ ENDFOOTNOTE.

ENDFOOTNOTE.

7-64. Diagram with crosscurrent [2] is called such, with which directions of flows of both media are mutually intersected.

FOOTNOTE [2]. To diagrams with crosscurrent relate such, whose number of courses does not exceed four. Usually with a larger number of courses these diagrams are considered as anti- or direct-flow/ramjet. ENDFOOTNOTE.

The temperature head for crosscurrent depends in essence on a quantity of courses and total mutual direction of the flows of media (straight/direct or countercurrent).

Mixing conditions in the limits of courses and between the courses at the values of coefficient ψ>0.85 weakly affect the value of the temperature head. Since the use/application of surfaces ψ<(0.8- [text missing] is recommended, the conditions for mixing during the determination of the temperature head for crosscurrent during the construction of nomogram are accepted for all cases of calculating the elements/cells of boiler aggregates/units identical: both media in the limits of courses are not mixed, but mixing occurs only between the courses. Since even with the air circulation or gases in the interpipe space occurs only very insignificant mixing in

the perpendicular to flow direction, this generalization of mixing conditions is completely admissible.

Coefficient $\psi$ is determined on nomogram XV, moreover different lines of its left half are used for the appropriate number of courses, namely:

the curve I - for once crosscurrent;

straight line 2 - for twofold crosscurrent;

curve 3 - for threefold crosscurrent;

curve 4 - for fourfold crosscurrent.

For the use of nomogram preliminarily are calculated the same dimensionless parameters, as at the in parallel mixed current:

$$P = \frac{\tau_{\text{м}}}{t'_{\text{б}} - t'_{\text{м}}}$$

and

$$R = \frac{\tau_{\text{б}}}{\tau_{\text{м}}}.$$

where $\tau_{\text{б}}$ - full/total/complete temperature differential of that medium where this drop/jump is greater than a drop/jump in second medium $\tau_{\text{м}}$ of °C;

$\vartheta'$ and t' - initial temperatures of heating and heating media, °C;

As can be seen from the designation of the values, entering the determining parameters, there is no need for distinguishing the conditions of mixing by that heating and the heating media.

7-65. Nomogram XV is suitable for calculating diagrams with repeatedly crosscurrent only in general/common/total countercurrent mutual flow direction. In the general/common/total direct-flow/ramjet direction in terms of the obtained values of parameters P and R is designed temperature:

$$P_1 = \frac{1 - [1 - P(R+1)]^{\frac{1}{n}}}{R+1}. \quad (7\text{-}77)$$

where n - a number of courses in designed heat exchanger.

By value $P_1$ and value of parameter R with the help of curve I of nomogram XV is determined coefficient of $\psi$ for entire heat exchanger.

7-66. Lines of nomogram XV, intended for determining temperature head with repeatedly crosscurrent, are constructed for case of equality surfaces of heating different courses. However, for those cases when the surface of heating separate courses is separated not more than to 20o/o and in this case specific according to the

nomogram for the entire heating surface coefficient $\psi \geqslant 0{,}90$. it should be used this nomogram.

In the presence of the larger disagreement of the surfaces of heating different courses or at the smaller value of coefficient the calculation of the temperature head is conducted separately on the sections (see Section 7-67).

Sections are separated in such a way that in the limits of each of them the surfaces of courses would be identical or they differed not more than to 20o/o. After this the temperature heads for each section are determined on the corresponding curved nomogram XV.

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7-67. When connection of heating surface differs from those examined earlier and is not satisfied the condition

$$\Delta t_{npw} \geqslant 0{,}92\Delta t_{npm},$$

calculation of temperature head is produced on individual sections of heating surface. In this case, just as during the conclusion/derivation of average/mean temperature head for the dismantled/selected diagrams, the coefficient of heat transfer within the limits of the heating surface is received as constant. Being assigned by the value of intermediate temperature of one of the

media, should be to determine from the equation of heat balance the corresponding to it temperature of the second medium, also, according to these temperatures designed the temperature heads for sections. The correctness of the selection of intermediate temperatures is determined by satisfaction of the condition

$$\frac{Q_1}{Q_2}=\frac{\Delta t_1 H_1}{\Delta t_2 H_2}, \qquad (7\text{-}78)$$

where $Q_1$ and $Q_2$ - heat absorptions of each section per 1 kg of one of the media, determined taking into account the intermediate temperature accepted, kcal/kg;

H and Δt - with respect to the heating surface and the calculated temperature heads of each section, m² and °C.

After the selection of intermediate temperatures is determined average/mean for the entire heating surface temperature head according to the formula

$$\Delta t_{cp}=\frac{\Delta t_1 H_1+\Delta t_2 H_2}{H_1+H_2}\ {}^\circ C. \qquad (7\text{-}79)$$

7-68. In cases of considerable changes in heat capacity of one of media (see Section 7-57), and also change of state of aggregation of medium within limits of designed surface of heating (considerable change in heat capacity of vapor at high pressure, transition from preheating to evaporation and from evaporation to superheating) immediate determination of temperature head for entire heating

surface from final temperatures leads to considerable error. Method of calculation in this case is the determination of the temperature heads for each of the sections in which total heat capacity is received as constant, with the subsequent averaging of these pressure heads according to the formula

$$\Delta t_{cp} = \frac{Q_1 + Q_2 + \ldots}{\frac{Q_1}{\Delta t_1} + \frac{Q_2}{\Delta t_2} + \ldots} \text{ °C}, \qquad (7\text{-}80)$$

where Q - heat absorptions of sections on 1 kg of one of the media kcal/kg;

Δt - the temperature heads in the sections, °C.

In certain cases, indicated below, with variable/alternating heat capacity of one of the media it is possible to use the simplified methods of calculating the temperature head.

7-69. For economizers, in which water is partially vaporized ("boiling"), connected on countercurrent and working with vapor content of steam-water mixture, which emerges from economizer, x≤30o/o, sufficient for calculation precision/accuracy of determination of temperature head is obtained with substitution instead of final temperature of water of conditional temperature

$$t_{усл} = t_{кип} + \frac{\Delta i_n}{2} \text{ °C}, \qquad (7\text{-}81)$$

where $\Delta i_{\text{к}} = i'' - i_{\text{кип}}$ – quantity of heat, spent on vaporization, in reference to 1 kg of passing through economizer water, kcal/kg;

$i''$ – enthalpy of steam-water mixture on output/yield from economizer, kcal/kg;

$i_{\text{кип}}$ – enthalpy of boiling water at pressure in drum, kcal/kg;

$t_{\text{кип}}$ – boiling point at this pressure, °C.

The applicability of this simplified method of calculation is limited by the specific smallest values of a difference in the temperatures of gases and water for the "cold" end of the economizer or its separately designed step/stage at the prescribed/assigned temperatures of water at the entrance into the economizer and a pressure in the boiler. At the values of a difference in the temperatures at the "cold" end than less indicated in the given below table, the calculation of the temperature head must be carried out in sections.

| Давление в котле p, ата (1) | <14 | >14 | | |
|---|---|---|---|---|
| Температура воды при входе в рассчитываемую ступень экономайзера t', °C (2) | ≥20 | 100÷139 | 140÷179 | ≥180 |
| Наименьшая разность температур, °C (3) | ≥100 | ≥150 | ≥110 | ≥60 |

Key: (1). Pressure in bciler p, ata(abs.). (2). Temperature of water upon entrance into desiqned step/stage of eccnomizer t',°C. (3). Smallest difference in temperatures of °C.

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7-70. Superheaters or their separately designed steps/stages with high initial humidity cf steam (after mcistening in steam cooler) when

$$\frac{(1-x)r}{i_{ne}-i_x} \leqslant 0.12, \qquad (7\text{-}82)$$

one should design normally, without taking into account initial humidity of steam.

In equation (7-82) (1-x) - the humidity cf steam entering superheater; r - heat of vaporization kcal/kg; $i_{ne}$ and $i_x$ — enthalpy of overheated and wet steam, kcal/kg.

If superheater the two-stage and temperature head of first stage

is designed separately, satisfaction of condition (7-82) should be checked for this step/stage. With the nonobservance of condition (7-82) the temperature heads of the sections of evaporation and superheating are designed separately and they are neutralized according to formula (7-60).

If condition (7-82) is not satisfied in the superheaters, connected on the diagram of consecutive-mixed current, calculation according to the sections is produced as follows.

Fraction/portion A of the direct-flow/ramjet surface (see p 7-61) in the section of superheating approximately is determined according to the expression

$$A' = \frac{H_{npm}}{H\left[1 - \frac{(1-x)r}{i_{ne} - i_x}\right]},$$

where H - a surface of heating entire superheater, $m^2$.

Further, by the final temperatures of gases and steam for the section of superheating determine parameters P, R and temperature head at the countercurrent. Using nomogram XII, is found coefficient of ψ and they determine the temperature head for the section of superheating.

If parameters P and R for the section of superheating exceed the

limits, encompassed by the curves of nomogram of the XIII, the calculation temperature head in this section is conducted separately for both courses according to the intermediate temperatures of gases and steam. After the selection of intermediate temperatures is designed from formula (7-79) average/mean temperature head for the first (on the steam) course of superheater and from formula (7-78) they check the correctness of the selection of temperatures between the courses. In the case of the nonperformance of condition (7-78) make more precise these temperatures.

The averaging of the temperature heads for the sections of superheating and evaporation is produced according to formula (7-80).

The calculation of the temperature head in superheater with the high initial humidity of steam, connected according to the diagram of parallel-mixed current, is produced analogous method. During the calculation of such superheaters it is in parts conditionally accepted that the flue is divided between the courses by longitudinal baffles, and the relation of the gas flows on the chosen parts of the flue is equal to the relation of the surfaces of heating the corresponding courses. The coefficients of heat transfer for different courses are received as identical ones. For the calculation are assigned the value of temperature of steam between the courses. By this value and known temperatures of steam on the entrance into

the superheater and the output/yield from it, and also the temperature of the gases before the surface they are determined from the equation of the balance of the value of the temperature of gases after each course.

After the calculation of the temperature heads for the separate courses the correctness of the value of intermediate temperature of accepted steam is checked using equation (7-78). The temperature head for the course, which consists of the evaporative and superheater parts, is designed from formula (7-80).

7-71. For calculating temperature head in superheaters of high-pressure boilers or their parts at pressure of steam is above 125 Am(gage) and superheating in designed part it is more than for 120°C over saturation temperature, one should divide superheater in two sections, carrying in fraction/portion of the first (on course of steam) of 1/3 full/total/complete heat absorptions of superheater. On the tables of appendix II is determined the temperature of steam on the boundary/interface of sections and on it from the equation of balance - temperature of gases. The temperature heads of sections are averaged according to the formula

$$\Delta t_{cp} = \frac{3\Delta t_1}{1 + 2\frac{\Delta t_1}{\Delta t_2}}.$$

If this superheater is connected on the diagram of consecutive with parallel-mixed current, the calculation of the temperature head

should be conducted for each course individually, accepting heat capacity of steam in the limits of the course by constant, or employing procedure, analogous that presented for such superheaters in p. 7-70.

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Chapter Eight.

RECOMMENDATIONS REGARDING THE PROCEDURE OF CALCULATION OF BOILER AGGREGATE/UNIT.

8-A. Indications about order and sequence of calculation.

8-01. During rational design of boiler aggregate/unit or its separate elements/cells by prescribed/assigned temperatures of flue gases and heating medium are determined values of heat absorption of each element/cell, after which are designed temperature head and coefficient of heat transfer and from equation of heat exchange (7-01) is located value of surface of heating.

8-02. Verifying calculation of boiler aggregate/unit or its separate elements/cells is more general case, since even during planning of new aggregates/units surface of heating separate elements/cells is determined by general/common/total layout considerations and subsequent verifying calculation it is made more precise their heat absorption.

During the verifying calculation of entire aggregate/unit unknowns are not only the intermediate temperatures of flue gases and heat-transfer agent, but also the final temperatures of stack gases, preheating of air and - sometimes - superheating vapor. For executing the calculation it is necessary to be assigned by these temperatures and to make more precise their method of successive approximations.

During the verifying calculation of separate convective surfaces are assigned usually the temperature and the enthalpy of each of the transferring heat media only at one end of the heating surface. For determining enthalpy of both media at the second end it is necessary to be assigned by the value of heat absorption and to make more precise its method of successive approximations.

Since the execution of successive approximations most of all complicates calculation and increases the expenditure of time for it, are given below some recommendations about order and sequence of calculating the separate convective surface of heating and entire aggregate/unit as a whole in connection with more complicated verifying calculation.

8-03. Calculation of boiler aggregate/unit must ensure necessary precision/accuracy of determination of basic parameters, first of all of temperatures of superheated steam and stack gases.

During the estimaticn of the cbtainable accuracy of calculation one should consider that some values, which lie at the basis of calculation, in particular the ccefficients cf heat transfer, are determined with comparatively large errors.

The recommended precision/accuracy of calculation must be based on combined analysis of its desirable and obtainable accuracy. This analysis shows that during the thermal design sufficient precision/accuracy of computational operations is ensured by calculation with the help of the slide rule with a length of 25 cm. From the same analysis escape/ensue the led in chapter 8 recommendations about the necessary precision/accuracy of successive approximations with calculation of separate flues and aggregate/unit as a whole.

Execution of calculation with the precision/accuracy of larger than gives the slide rule, and achievement cf the higher precision/accuracy of successive approximaticns, than it is recommended below, to allow/assume one ought not, since this does not change the precision/accuracy of final results and cnly increases the volume of computational work.

8-04. During verifying calculation of convective surface preliminarily is estimated unknown final temperature and, consequently, also enthalpy of one of media and, solving together equations of heat balance (see Section 7-02), determine those corresponding to temperature accepted heat absorption of surface and final enthalpy of second medium. After this is designed the coefficient of heat transfer and the temperature head and according to the equation of heat exchange (7-01) determine value the heat absorptions of the surface of heating, in reference to 1 kg (1 nm³) of fuel/propellant.

If the obtained from the equation of heat exchange value of heat perception $Q_m$ kcal/kg it differs from specific according to the equation balance $Q_б$ kcal/kg not more than by 2o/o (sometimes, indicated in the subsequent sections, it is more), the calculation of surface is not made more precise. As the final values of temperatures and heat absorptions are considered those which entered into the equations of balance.

In the presence of the disagreement between both values of heat absorption $Q_m$ and $Q_б$ of larger the limit indicated, they take the new value of final temperature and repeat the calculation. When selecting this temperature and repeating the calculation should be been guided the given below indications.

If with the first approximaticn value $Q_m$ proved to be more than the heat absorption, determined according to the equation of balance $Q_6$, the value of final temperature for the second approximation/approach is received by such so that the difference between the temperatures, flue gases at the entrance and the output/yield would be mcre than with the first approximation, and vice versa.

For the second apprcximaticn/approach it is expedient to select the value of temperature, differ from that accepted with first approximation is not mcre than by 50°C. In this case the coefficient of heat transfer counted over should not be in view of its small change. Should be to count over only the values of the temperature head and again solved the equaticns of balance and heat exchange.

Even if after the second approximation/approach the disagreement between values $Q_m$ and $Q_6$ proves to be more than the limit indicated, actual temperature is lccated withcut the subsequent approximation/approach with the help of linear interpolation.

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Interpolation can be carried out analytically or graphically.

During analytical interpolation computed value of the unknown final temperature will be determined from the equality

$$\vartheta''_{p}=\vartheta''_{II}+(\vartheta''_{II}-\vartheta''_{I})\frac{(Q_{\text{б}}-Q_{m})_{I}}{(Q_{\text{б}}-Q_{m})_{I}-(Q_{\text{б}}-Q_{m})_{II}}; \quad (8\text{-}01)$$

indices I and II relate respectively to the first and second approximations/approaches.

The order of the determination of the unknown value of temperature $\vartheta''_{p}$ by the method of graphic interpolation is clear from Fig. 7.

If determined by the method of interpolation computed value of temperature differs from that, on which was determined the coefficient of heat transfer, not more than on 50°C, then for the termination of the calculation of necessary according to this temperature to make more precise only heat absorption and unknown temperature of the heat-absorbing medium from the equation of balance. In the presence of the larger disagreement it is necessary according to this temperature to repeat calculation, including the determination of the coefficient of heat transfer and temperature head.

8-05. Calculation of aggregate/unit as a whole with single-stage layout of tail heating surfaces is recommended to conduct in this sequence.

Preliminarily are estimated the temperatures of stack gases and preheating of air. By the temperature of stack gases accepted they are determined loss with the stack gases and taking into account the remaining losses the efficiency of aggregate/unit, while on the latter - a fuel consumption.

After this is designed the temperature of gases at the output/yield from the heating and are further - by successive approximations - the subsequent heating surfaces to the economizer.

The calculation of heat perception of economizer is produced also by method of successive approximations. Known in this case is the temperature of gases at the entrance into the economizer, which was determined from the calculation of the previous heating surface, and the temperature of water at the entrance into the economizer. By calculation are determined the temperatures of gases and water after the economizer.

In the calculation of air preheater known are the temperature of gases at the entrance, determined from the calculation of economizer,

and the temperature of the air, supplied to the aggregate/unit (in general - cold). By method of successive approximations are determined the temperatures of stack gases and hot air.

If the obtained as a result of calculation temperature of stack gases differs from that accepted in the beginning of calculation not more than by ±10°C, and the temperature of hot air - is not more than on ±40°C, the calculation of heat exchange in the boiler is considered completed and the obtained temperatures by final ones, since the following approximation/approach can refine them only 2-3°C. With the error in estimation of the temperature of the heated air, which reaches to 40°C, the outlet temperature of the heating will be changed not more than on ±10°C, which virtually will not affect the results of calculating the subsequent heating surfaces.

For the termination of calculation are made more precise taking into account the obtained value of the temperature of stack gases the heat loss with the stack gases the efficiency of aggregate/unit and the fuel consumption. Further, in terms of computed value of the temperature of hot air and by that determining in the basic calculation the temperature of gases at the output/yield from the heating is made more precise according to formulas (6-06)-(6-08) the heat absorption of the beam-receiving surfaces, in reference to 1 kg of fuel/propellant.

After the refinement of balance values is determined the calculated discrepancy of the heat balance of aggregate/unit according to the formula

$$\Delta Q = Q_p^p \eta_{к.а} - (Q_л + Q_к + Q_{пе} + Q_{эк}) \left(1 - \frac{q_4}{100}\right) \text{ккал/кг}^{(1)} \quad (8\text{-}02)$$

Key: (1). kcal/kg.

where $Q_л, Q_к, Q_{пе}$ and $Q_{эк}$ – quantities of heat, taken on 1 kg of fuel/propellant by the beam-receiving surfaces of heating, by boiler bundles, superheater and economizer, kcal/kg; into the formula substitute the value themselves of heat absorptions, determined from the equations of balance.

The value of discrepancy with the correct execution of calculation is close to zero and in any case must not exceed 0.5o/o from $Q_p^p$

If the specific as a result of calculation temperature of stack gases differs from that accepted in the beginning of calculation more than to ±10°C or disagreement between taken and computed values of the temperature of hot air of more than ±40°C, calculation must be repeated. For the repeated calculation are assigned by the new values

of the temperatures of stack gases and hot air, equal to found of the first calculation or by close ones to them, in the dependence on that occurred during the first calculation the disagreements of these values.

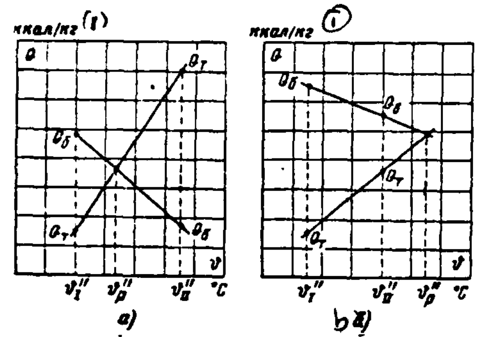


Fig. 7. Graphic determination of calculated temperature $\vartheta_p''$.

Key: (1). kcal/kg.

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If the disagreement of the values of the temperature of the stack gases, accepted with the first and second approximations/approaches, leads to a change in the calculated fuel consumption not more than to 2c/c, the coefficients of heating with the second approximation/approach on are counted over; they are made more precise only the value of temperatures, temperature heads and heat perceptions through entire channel [1].

FOOTNOTE [1]. When for the determination of the characteristic of aggregate/unit are necessary to perform several verifying

calculations to different boiler ratings, it is possible to manage without successive approximations, the system of characteristic for the coefficients of evaporation, not prescribed/assigned, but which were determined from the calculations according to the method MEI (for example, see T. Kh. Margulova. Layout and thermal calculation of boiler unit, Gosenergoizdat, 1956). ENDFOOTNOTE.

8-06. Order of calculation with two-stage layout of tail heating surfaces remains in basic the same, as it is shown in p. 8-05. Below are stated its only necessary changes.

After the calculation of all surfaces of heating, arranged/located according to the course gases to the second [2] step/stage of economizer, known is only the temperature of gases at the entrance into this step/stage.

FOOTNOTE [2]. Sequence of steps/stages in all cases is determined in the course of heating medium. ENDFOOTNOTE.

It is necessary to assign the value of the enthalpy of water at the output/yield from the economizer. For its rough estimate is comprised the following equation:

$$i''_{эк} = \frac{D}{D_{эк}}(i_{пе} + \Delta i_{по}) - \frac{B_p}{D_{эк}}(Q_л + Q_к + Q_{пе})\ ккал/кг, (1) \qquad (8\text{-}03)$$

where $i_{пе}$ – enthalpy of the superheated steam before main steam

catch, kcal/kg;

$D_{w}$ - flow rate of the water through economizer, kg/h;

$\Delta i_{no}$ - heat perception of the surface/skin steam cooler, cooling water from which is supplied into economizer, kcal/kg.

If the heat, taken away from the vapor in the steam cooler, is transmitted to water or steam-water mixture after the economizer, then into formula (8-03) $\Delta i_{no}$ it is not introduced. Remaining designations - the same as in formula (8-02).

On found in this way enthalpy i" is determined the temperature of water at the output/yield from the economizer. According to this temperature and known temperature of gases at the entrance is designed by method of successive approximations the second step/stage of economizer.

The temperature of gases at the entrance into secondary air heater is known from the calculation of the previous heating surface. The calculation of this step/stage is conducted according to the value of the temperature of hot air, accepted in the calculation of heating.

The calculation of first stage of economizer is conducted according to the known from the calculation of the previous heating surface temperature of gases and prescribed/assigned to temperature water at the stage inlet. By method of successive approximations are determined the temperatures of gases and water for output/yield from the designed step/stage of economizer. The in general obtained temperature of water at the output/yield of first stage will not coincide with the designed previously value of the temperature of water for the entrance into the second step/stage.

The calculation of first stage of air preheater is conducted according to known from the calculation previous surface to the temperature of gases and to the prescribed/assigned temperature of air at the inlet into the air preheater. By method of successive approximations are determined the temperatures of stack gases and hot air for output/yield from the designed step/stage. In general these temperatures also do not coincide with that accepted in the beginning of calculation by the temperature of stack gases and specific earlier temperature of the heated air by the entrance into secondary air heater.

If the specific as a result of calculation temperature of stack gases differs from that accepted in the beginning of calculation not more than by $\pm 10^{\circ}C$ and simultaneously the discrepancy between the

intermediate values of the temperatures of water and air, determined from calculation of both steps/stages of economizer and air preheater, do not exceed ±10°C each, the calculation of heat exchange in the boiler is considered finished. At conclusion of calculation are made more precise balance values and is determined the discrepancy of balance according to indications p. 8-05.

If the obtained temperature of stack gases differs from that accepted not more than by ±10°C, but any of the discrepancies between the intermediate values of the temperatures of water and air exceeds ±10°C, it is necessary to repeat the calculation of economizer and air preheater. In this case in contrast to the previous calculation the second steps/stages of economizer and air preheater are calculated by accepted temperatures of water and air at the entrance; the values of these temperatures take as the equal to the outlet temperatures from first stages, determined with the first approximation.

With the deviation of that obtained as a result of calculating the temperature of stack gases from that accepted, larger ±10°C, should be repeated the calculation of entire aggregate/unit in accordance with the indications p. 8-05. It should be the temperature of preheating air accepted close one to the value which would be obtained with the first approximation, if to the determined

temperature of air at the output/yield from first stage of the air preheater increased the calculated temperature differential of air in secondary air heater.

The recommended sequence allows, as a rule, with the execution of calculating the boiler aggregate/unit to be bounded to twc approximations/approaches.

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8-07. In course of computation considerable difficulties are caused by determination cf heat absorption of different additiona small heating surfaces, connected in parallel or consecutively/serially (cn course of gases) with basic surfaces of heating and having independent designations/purposes (wall shields in region of boiler bundle cr screen superheater, suspension ducts of superheater, outlet pipes of econcmizers on walls or ceiling of flues, warmed water flcw ducts, etc.). For calculating such surfaces are recommended the follcwing simplifications.

If the additional heating surface comprises not more than 4o/o basic surface, it separately is not designed, but it is included in the surface of the tube bank, series-connected with it on the internal medium.

In such cases when additional surface composes 4-10o/o of surface of basic flue, the calculation of its heat absorption is produced separately on the given below indications.

The coefficient of heat transfer in the additional heating surface is received by the same as for the basic surface, without depending on design of both. Its heat absorption is estimated preliminarily and it is adjoined to the value of the heat absorption of basic surface during the determination of the final temperature of gases. Testing the value of heat absorption accepted is produced taking into account the value of the temperature head in the additional heating surface.

The temperature head for the additional surface, situated in parallel (on the course of gases) to basis, takes as the equal to difference in mean temperatures of gases in the flue and heat-transfer agent in the additional surface.

The temperature head for consecutively/serially (on the course of gases) the arranged/located additional surface takes as the equal to difference in the temperature of gases at the output/yield from the flue and mean temperature of heat-transfer agent in the

additional surface.

Is allowed/assumed the disagreement by that accepted and that determined of the values of the heat absorption of additional surface to ±10o/o.

The surface of heating the ducts, arranged/located on the bricking, is determined on their half-perimeter, with exception of the cases of the separate calculation of cavity emission (see Section 7-39).

8-08. Is recommended following order of arrangement of calculation data:

1) initial data in accordance with assignment with respect to p. 1-04 or 1-05;

2) excess air on flues;

3) volumes, volume fractions of triatomic gases and enthalpy of gases and air;

4) heat balance of aggregate/unit and determination of fuel consumption;

5) calculation of heating;

6) calculation of scallop and first convection bank;

7) calculation of superheater;

8) calculation of subsequent boiler bundles;

9) calculation of economizer;

10) the calculation of the air preheater;

11) the summary table of basic data of calculation according to the aggregate/unit as a whole.

8-B. Calculation of heating.

8-09. During rational design volume of heating is determined by recommended values of thermal stress of furnace cavity (see RN 5-02-5-05). The sizes/dimensions of furnace chamber/camera are selected in accordance with the recommendations of appendix V. Further, are determined beam-receiving surface $H_\wedge$ and temperature

of gases at the output/yield frcm heating $\vartheta''_{т}$. This temperature must ensure the absence of slagging the heating surfaces, situated after the heating. Its value should be selected in accordance with the recommendations of appendix V. Calculaticn $H_{л}$ and $\vartheta''_{т}$ is conducted according to one of the following versions.

The first is characteristic fcr the boilers of the small and average/mean powers when according to the working conditions cf heating is not required the sclid shielding cf network/grid. In this case according to the prescribed/assigned temperature of gases at the output/yield from the heating are designed sizes/dimensions $H_{л}$.

With the second version of calculation, which relates to the heatings of the boilers cf the large power, in which is accomplished/realized the solid shielding of network/grid, according to nomogram I or formula (6-04) is determined value $\vartheta''_{т}$. If this value proves to be that above permitted, it is necessary to provide an additional shielding cr an increase in the volume of heating for guaranteeing the required degree cf colling of gases.

During the verifying calculation by the prescribed/assigned structural/design sizes/dimensicns of heating and shields is determined also the outlet temperature from furnace chamber/camera $\vartheta''_{т}$

8-10. Temperature cf gases at output/yield from heating is considered temperature in section/cut before ducts of arranged/located on output/yield from furnace chamber/camera rarefied scallop or bundle. Only with very rare run of pipes. Only with very rare run of pipes when step/pitch in the width of flue $s_1>4d$ and simultaneously $s_2>6d$, as the calculated is considered temperature after these ducts; in this case the full/total/complete surface of rarefied runs of pipes it is included in the beam-receiving surface.

When the screen heating surfaces are present, by the temperature of gases at the output/yield from the heating is counted the temperature before screens. In acccrdance with this in the beam-receiving surface of heating is included only the surface area, which passes along the axes of first run of pipes of the screen surfaces (see Section 4 cf SN 6-03). The gas volumes between the screens are not included in the volume of heating.

One should consider that in the presence of screen surfaces given in appendix the V maximum permissible according to the conditions slaggings of the temperature cf gases relate to the section/cut behind the screens.

For the low-power reactors with afterburners of the temperature of gases at the output/yield from the heating is counted the temperature after afterburner.

8-11. Beam-receiving surface at prescribed/assigned outlet temperature from heating is determined from nomogram I or formula (6-03).

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For the use of formula it is necessary to preliminarily estimate emissivity factor of heating $a_m$. For this one should to assign the value of the degree of the shielding of heating $\psi$, to determine emissivity factor of burner $a_\phi$ also, on the indication RN 6-02 determine $a_m$. After the determination of the beam-receiving surface and refinement of the sizes/dimensions of heating it is necessary to test conformity between tentatively accepted and obtained as a result of calculation by the values of the degree of the shielding of heating. The disagreement of these values must not exceed ±5o/o of calculated value $\psi$.

8-12. Calculation of temperature of gases at output/yield from heating with prescribed/assigned structural/design characteristics of heating is produced on formula (6-C4) or nomogram I.

For thi: on the drawings are determined according to paragraphs 6-13-6-15 volume and beam-receiving surface of the heating; according to formula (6-10a) or (6-10b) is designed the degree of shielding, according to formula (6-15) - efficient emissivity factor of flame, on RN 6-02 - emissivity factor of heating. The average/mean total heat capacity of combustion products $Vc_{cp}$ is determined from formula (6-05). For determination $a_{\phi}$ and $Vc_{cp}$ preliminarily are assigned the value of outlet temperature from the heating. If specific of the nomogram I or formula (6-04) the output temperature of gases differs from that accepted more than by ±100°C, should be made more precise values $Vc_{cp}$ and $a_{\phi}$ in terms of the determined from the calculation value of the temperature of gases. After this is determined the value of the output temperature of heating.

8-C. Calculation of boiler bundles and scallop.

8-13. From calculation of heating or previous heating surface known are temperature and enthalpy of gases, which enter into designed boiler bundle.

During the rational design, i.e., during the determination of the necessary surface of heating bundle, the temperature of gases

after the bundle is prescribed/assigned. During the calculation of the first bundle this temperature must be matched with the conditions of guaranteeing the reliability of the work of the ducts of the superheater (see appendix IV).

During the verifying calculation the temperature of gases after the bundle is accepted with the subsequent testing and its refinement.

The quantity of heat, received by boiler bundle from the combustion products 1 kg or 1 $nm^3$ of fuel/propellant, is determined according to the equation of balance (7-02).

8-14. Temperature head in all cases is determined from formula (7-66) or (7-67), since temperature of heating medium is permanent and equal to boiling point at pressure in boiler barrel.

Mean temperature of flow is determined from formula (7-25).

By the calculated temperature of flow are determined from formula (7-13) average/mean gas velocities in the sections with the longitudinal and transverse flow. The volume of the products of the combustion 1 kg ($nm^3$) of fuel/propellant is substituted with the average/mean excess air, in the bundle, and in the case when suction

in the first bundle takes as equal to zero, with the excess air in the heating.

8-15. With transverse flow of bundle, formed from ducts of different diameters, acccrding to formula (7-31) is determined mean diameter. With the transverse flow of checkered bundles with different spacings between tubes according tc formula (7-30) are determined average/mean steps/pitches. Clear cpening for the pass cf gases is determined frcm formula (7-18) cr (7-23). With mixed flow should be been guided the indications RN 7-03.

8-16. Convection heat-transfer coefficient during transverse flow is determined in depending on shape of beam (corridor or checkered) on nomogram II or III. During the cblique flow around corridor bundles with the angle between the flow direction and the axes/axles of ducts of <80° obtained from nomcgram II value , is multiplied by 1.07 (see Section 7-26).

Convection heat-transfer coefficient during the longitudinal flow is determined on ncmogram IV, for which preliminarily according to formula (7-35) is designed the equivalent diameter of flue. Since in such cases the ratio cf path length in the section of longitudinal flcw to the equivalent diameter of flue is usually small, is necessary to consider correction fcr relation $l/d_e$

During the mixed flow the obtained values of heat-transfer coefficients are neutralized according to formula (7-39).

Festoon, formed from the mixed along the flow gases of the ducts of shield, is designed as common checkered bundle.

During the calculation of bundles with the noticeable incompleteness of the sweep of gases of the surface of heating (for example, the beams of low-power reactors) the obtained by the methods indicated convection heat-transfer coefficient is multiplied by the coefficient of the incompleteness of flow $\omega$, determined on the indications RN 7-03.

8-17. For determining radiation heat-transfer coefficient in interpipe space of bundle preliminarily in formula (7-48) or (7-49) is found average/mean efficient thickness of radiation layer. Spacings between tubes are determined by the real distance between centers of ducts in basic part of the bundle without taking into account of unit breakage or gullets.

Cavity emission to the bundles is not considered.

8-18. Through indications p. 7-38 is located mean temperature of contaminated wall of ducts of bundle. In formula (7-50) is substituted the calculated surface of heating bundle $H_p$ see p. 8-20.

Then in values $p_n \cdot s$, $r_{H_2O}$, $\mu$ and s according to indications paragraphs 7-33 and 7-34 with the help of nomograms IX-XI is located heat-transfer coefficient by the interpipe radiation/emission of combustion products.

8-19. On nomogram XII is determined contamination factor of surface of heating bundle. Computed value of the coefficient of heat transfer is found by formula (7-10b).

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8-20. Since heat absorption of heating surface from radiation/emission of heating sharply raises temperature of contaminated wall of ducts, in calculation of first bundle and festoon it is accepted that heating surface, which receives radiation/emission from heating (beam-sensing surface of bundle), does not participate in heat exchange by convection and intertube radiation/emission. Therefore the calculated surface of heating the first bundle is defined as the difference between the full/total/complete and beam-receiving surfaces of heating bundle from the equality

$$H_p = H - H_{лп} \text{ м}^2, \qquad (8\text{-}04)$$

where H - a full/total/complete surface of heating bundle, m²; $H_{лп}$ - its beam-receiving surface, m².

With a number of series/rows of bundle, the equal or larger to five, it is accepted that entire heat, which falls from the heating to the bundle, by it is absorbed. With a smaller number of series/rows the part of the heat is passed through the bundle and it

is absorbed by the subsequent surfaces. To account this necessary to determine in formula (6-12) the angular coefficient of beam $x_{пуч}$ and value

$$H_{чп} = x_{пуч} H_{лк} \ м^2, \qquad (8\text{-}05)$$

where $H_{лк}$ - beam-receiving surface of convecticn bank with x=1, m².

8-21. During rational design from fcrmula (7-01) is determined calculated surface of heating bundle, which participates in convective heat exchange. For the first bundle and the festoon the full/total/complete heating surface will be determined from the equality

$$H = H_p + H_{лп} \ м^2. \qquad (8\text{-}06)$$

8-22. In the case of verifying calculaticn of bundle according to equation of heat transfer (7-01) is determined quantity of transmitted to surface heating of heat, in reference to 1 kg (nm³) of fuel/propellant.

If the disagreement between the values of heat absorptions, determined according tc the equaticns of balance and heat transfer, does not exceed 2o/o for the boiler bundles and 5o/c for the festoons formed from the outlet pipes of shields, calculaticn is not made more precise.

In the presence of the large disagreements should be

manufactured repeated calculation in accordance with the indications p. 8-04.

8.23. Calculation of heat transfer in screen shields, arranged/located on output/yield from heating, is produced analogously with calculation of screen superheaters whose methodology is presented in p. 8-38.

8-D. Calculation of superheater.

8-24. During rational design of superheater quantity of heat $Q_{пе}$ kcal/kg, which must be transmitted in superheater on 1 kg of fuel/propellant, is determined from equation of balance (7-03a) for prescribed/assigned temperature of superheating and heat absorption of steam cooler accepted.

During the verifying calculation of superheater for determination $Q_{пе}$ the heat absorption of steam cooler (or the temperature of superheating) is accepted with the subsequent testing and the refinement.

If on the superheater falls the part of the heat of radiation from heating $Q_л$ kcal/kg, this heat is introduced in equation (7-30a). Value $Q_л$ must be determined with consideration the angular

coefficient of the arranged/located before the superheater festoon and variation factor heat distribution in the furnace chamber/camera.

In the presence of the selection of the saturated steam into formula (7-03a) is substituted the expenditure/consumption only of superheated steam $D_{пе}$.

The humidity of the saturated steam, which emerges from the boiler barrel of contemporary construction/design, furnished with the normally working steam-separating devices, should be to take as equal to zero, i.e. enthalpy of steam $i'_{пе}$ kcal/kg taken as the equal to the enthalpy of dry saturated steam $i_{н.п}$ kcal/kg.

Final enthalpy of steam $i''_{пе}$ kcal/kg is found through the tables of appendix II for the given ones of pressure and temperature of steam before the main catch.

During the calculation of superheater in parts the heat absorption of the designed part is determined by the prescribed/assigned or taken temperatures of steam at the ends of this part. Design pressure on the boundary/interface between loose parts of superheater takes as the equal to the half-sum of the values of pressure in the boiler barrel and before the main catch.

In the presence of steam coolers the calculation for the nominal load is conducted taking into account their inclusion/connection. Of recommendations by choice the heat of the perceptions of steam coolers see p. 43 of appendix V. Additional indications in accordance with the calculation of superheater during the setting up of different steam coolers are given in p. 8-39.

8-25. By obtained value $Q_{ne}$ with the help of equation (7-02) are determined enthalpy and temperature of gases after superheater or that designed separately partly it.

If in the flue of superheater is arranged/located another, relatively small surface of heating (for example, the outlet pipes of economizer), which in accordance with the indications p. 8-07 should be designed separately, to value $Q_{ne}$ is added the preliminarily taken heat absorption of this surface.

8-26. Temperature head is calculated in dependence on design of superheater and mutual direction of flows of gases and steam in accordance with indications of paragraph 7-C.

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8-27. Further, is determined average/mean steam temperature

according to formula

$$t=\frac{t'_{ne}+t''_{ne}}{2}\ ^\circ C. \qquad (8-07)$$

where $t'_{ne}$ and $t''_{ne}$ - temperature of steam for entrance into superheater (designed part) and output/yield from it, °C.

Mean temperature of the flow of gases takes as, as usual, the equal to mean arithmetic value from the final temperatures.

8-28. Average/mean gas velocities in sections with longitudinal and transverse flow around ducts are determined from formula (7-13) for average/mean excess air in flue of superheater.

8-29. Heat-transfer coefficient of gases by convection $\alpha_k$ with transverse flow is determined on nomogram II or III in depending on type of bundle (corridor or checkered).

For the sections of longitudinal flow $\alpha_k$ it is determined on nomogram IV. Preliminarily according to formula (7-35) is designed the equivalent diameter of flue. With the mixed flow obtained values $\alpha_k$ are neutralized proportional to the appropriate heating surfaces according to formula (7-39).

8-30. On nomogram XII is determined contamination factor of superheater. According to formula (7-50) is determined mean

temperature of the contaminated wall of superheater. In the formula substitutes the value itself $Q_{л}$. Value $\alpha_2$ is determined on the indications p. 8-32.

8-31. Heat-transfer coefficient by intertube radiation/emission of combustion products is determined on nomograms IX-XI. The average/mean efficient thickness of radiation layer is found by formula (7-48) or (7-49) in depending on the diameter of coils and relative steps/pitches. Cavity emission, arranged/located to or within the superheater, is considered according to indications p. 7-39.

Cavity emission, located after the superheater, to superheater coils is not considered.

8-32. Heat-transfer coefficient from wall of duct to steam in view of its relatively small effect on value of coefficient of heat transfer can be determined with some simplifications.

The average speed of steam in the superheater is determined from the formula

$$w_n = \frac{D\upsilon}{3600 f_{nе}} \overset{(1)}{м/сек}, \qquad (8-08)$$

Key: (1). m/s.

where D - expenditure/consumption of steam through superheater, kg/h; v - average/mean specific volume of steam in superheater, $m^3$/kg.

For the calculation $\alpha_2$ it is possible to conditionally accept v equal to specific volume of steam at its average/mean temperature, rounding this temperature to the nearest smaller value, multiple of 10°C. Value v is determined on the tables of appendix II.

Mean pressure of steam in the superheater takes as the equal to the half-sum of pressures in the drum and before the main steam catch.

By the obtained average/mean values of pressure, temperature and speed of steam and tube bore is determined from nomogram the V heat-transfer coefficient from the wall to steam $\alpha_2$.

8-33. According to formula (7-10a) is determined coefficient of heat transfer of superheater. In the formula is substituted the obtained from nomogram XII value of contamination factor.

8-34. During rational design from formula (7-01) is found necessary surface of heating superheater.

8-35. During verifying calculation according to equalization of

heat transfer (7-01) is determined heat absorption of superheater. If it diverges from the value of heat absorption, calculated according to the equation of balance (7-02) or (7-03a), not more than to 2o/o (in the absence of steam cooler - not more than to 3o/o), the calculation of superheater is considered finished, but its heat absorption takes as the equal to the quantity of heat, determined from the balance according to formula (7-02) or (7-03a).

If disagreement of both values of heat absorption is more than the limits indicated, it is necessary to repeat calculation in accordance with the indications p. 8-04. In this case the recalculation of the coefficient of heat transfer is produced with a change in the final temperature of gases more than on 50°C; otherwise is counted over only temperature head. Heat-transfer coefficient from the wall to steam is not counted over in all cases.

If after recalculation the disagreement of obtained and taken heat absorptions proves to be more than permitted, they make more precise according to indications p. 8-04 the final temperature of gases. By this temperature they determine from formula (7-02) the heat absorption of superheater and according to formula (7-03a) make more precise the heat absorption of steam cooler or is found the temperature of superheating.

8-36. If with calculation of heat, returned by gases, is connected heat absorption of additional surface of heating (see Section 8-25), it is checked after calculation of superheater according to formula

$$Q' = \frac{H'k(\vartheta - t)}{B_p} \text{ ккал/кг}^{(1)}, \quad (8\text{-}09)$$

Key: (1). kcal/kg.

where H' - the actively washed by gases additional surface of heating, m²; k - coefficient of the heat transfer of superheater, kcal/m² hour deg; $\vartheta$ t - temperature of gases in the superheater and of heating medium in the additional surface of heating (see Section 8-07), °C.

8-37. Order of calculation of radiation (wall) superheaters following.

The heat absorption of radiation superheaters is defined as for the common screen surfaces, over the beam-receiving surface of radiation superheater $H_{лп}$.

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The average specific thermal load of the beam-receiving surfaces of furnace chamber/camera is determined from the calculation of the

heating:

$$q = \frac{B_p Q_л}{H_л}, \text{ккал/м}^2 \text{ час}, \quad (1)$$

Key: (1). kcal/m² hour.

where $B_p$ - the calculated consumption of fuel, kg/h; $Q_л$ - referred to 1 kg of fuel/propellant quantity of heat, transmitted by radiation/emission in the furnace chamber/camera, kcal/kg; $H_л$ - full/total/complete beam-receiving surface in the heating, m².

In depending on the type of combustion system and location of radiation superheater is determined from formula (6-25) the specific thermal load of the beam-receiving surface of latter $q_{пе}$.

The heat absorption of radiation superheater, in reference to 1 kg of fuel/propellant, is determined from the formula

$$Q_{л.пе} = \frac{H_{л.пе}}{B_p} q_{пе} \text{ kcal/kg} \quad (8-10)$$

After the determination of the heat absorption of superheater from the prescribed/assigned enthalpy of steam at the entrance they are determined from the equation of balance (7-03a) final enthalpy, also, with the help of the tables of appendix II temperature of steam.

8-38. Order of calculation of half-radiation (screen) superheaters, placed in exit section of furnace chamber/camera in the

form of separate strips/films with large transverse pitches, differs little from calculation cf convective superheaters.

Convection heat-transfer coefficient for the screens whose height is not more than the height of the output window of heating, is defined on nomogram II as for the common corridor bundle with the purely transverse of flow. For the screens, omitted into heating chamber/camera is lower than the output window of heating, convection heat-transfer coefficient is designed as for mixed flowing, according to formula (7-39). In this case the convection heat-transfer coefficients are determined as follows: for the transversely washed part - also on nomogram II, for the longitudinally washed part - on nomogram IV. For the use of nomogram IV should be preliminarily according to formula (7-35) calculated the equivalent diameter.

The method of laying out in the sections of transverse and longitudinal flow, and also determination of calculated clear openings is given in RN 7-03.

The efficient thickness of radiation layer is determined from formula (7-47), led for the convenience to the form:

$$s = \frac{1{,}8}{\frac{1}{a} + \frac{1}{b} + \frac{1}{c}} \text{ м}, \qquad (8\text{-}11)$$

where a, b and c - height, width and depth that of single chamber, formed by two adjacent screens, m.

The calculated heating surface is determined from formula (8-04); in this case full/total/complete surface is determined on the full/total/complete perimeter of ducts.

Contamination factor is defined on nomogram XII as for the convective superheaters. With the mixed flow by gas velocities in the appropriate sections are determined the contamination factors for the sections of transverse and longitudinal flow and they are neutralized on the indications p. 7-51.

The coefficient of heat transfer, in reference to the calculated heating surface, is determined from formula (7-10a).

The temperature head is determined from formula (7-67) as a mean arithmetic difference in the temperatures.

8-39. Presence of steam cooler of one or the other type causes some special features/peculiarities of calculation of superheater.

During the setting up of surface/skin steam cooler on the side of the saturated steam, if the heat absorption of steam cooler by the assigned magnitude of moistening steam, entering the superheater, X

kg/kg, initial enthalpy cf steam is calculated according to the formula

$$i' = i_{н.п} - r(1 - x) \text{ kcal/kg} \quad (8\text{-}12)$$

where r - heat of vaporization at a pressure in the bciler barrel, kcal/kg.

If the heat absorption of steam cooler is prescribed/assigned directly by the quantity of heat, loosened by 1 kg of steam to cooling water, $\Delta i_{по}$, initial enthalpy of steam is calculated according to the formula

$$i' = i_{н.п} - \Delta i_{по} \text{ kcal/kg}. \quad (8\text{-}13)$$

The admissibility cf the determination of the temperature head in the superheater withcut the acccunt tc initial humidity is checked using formula (7-82).

During the setting up cf surface/skin cr spray-type desuperheater "into the crosscut" the temperature head is designed separately for both parts acccrding to the actual temperatures in them, moreover are considered reductions in the temperature and enthalpy of steam upon transfer of one part of the superheater into another.

The heat-transfer coefficient can be taken as common for the entire superheater.

When setting the spray-type desuperheater "in the cross cut", the steam flow rate through the first part of the superheater D' according to the passage of the steam is less than the design flow rate of the superheated steam D by the amount of sprayed water $\Delta D$. The value of $\Delta D$ is connected with a reduction in steam enthalpy in the desuperheater $\Delta i_{no}$ by the following relationships;

$$\Delta D = D - D' = D \frac{\Delta i_{no}}{i_1'' - i_{ж}} \text{ кг/час (1)}; \quad (8\text{-}14)$$

$$\Delta i_{no} = i_1'' - i_{11}' \text{ ккал/кг (2)},$$

Key: (1). kg/h. (2). kcal/kg.

where $i_1''$ - steam enthalpy on the output from the first part of the superheater according to the passage of steam, i. e., on entry into the desuperheater, kcal/kg; $i_{11}'$ - steam enthalpy on exit from the desuperheater, i. e., on entry into the second part of the superheater, kcal/kg; $i_{ж}$ - enthalpy of the water, supplied to the steam cooler, kcal/kg.

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During the rational design of superheater with this steam cooler

they are usually assigned by temperature of steam at the output/yield from the first on the course of steam of the part of the superheater and by value $\Delta i_{no}$. Remaining balance values are determined from equation (8-14) and equations of heat balance (7-02) and (7-03a).

During the verifying calculation at first is designed the first on the course of gases part of the superheater. If it is first on the course of steam, then be assigned is expediently to preliminarily by value ΔD, if by the second on the course of steam, then are assigned the value $\Delta i_{no}$.

With the bypass damper control with the passage of part of the gas past the superheater the rational design is performed as follows: by the prescribed/assigned share of gases, passing through the superheater, are determined the enthalpy and the temperature of gases after the superheater and is designed its heating surface. When, in the bypass flue, the heating surface is present, it is designed taking into account the passage of the corresponding share of gases. After this according to the equation of mixing (7-07) are determined the enthalpy and the temperature of gases at the entrance into the subsequent heating surface. Verifying calculation is recommended to conduct differently in depending on whether there are or there are no heating surfaces in the bypass flue.

In the first case the calculation of the heating surfaces, situated in the basic and bypass flue, is conducted according to the value of the share of gases accepted, passing through this flue; the real distribution of gases is found by successive approximaticn. Enthalpy and temperature of gases upon the entrance into the subsequent heating surface are determined by heat content and temperatures of gases after each of the parallel flues with the help of the formula of mixing (7-C7).

In the absence of the heating surfaces in the bypass flue it is not necessary to determine the share of gases, passing through the shunted flue, since its value does not affect the enthalpy of the gases, which enter into the subsequent surface (after mixing). Should be only tested the sufficiency of the established/installed heating surface of superheater by calculation of it tc the passage of a full/total/complete quantity cf gases (taking into account the flow with the closed dampers cf bypass flue). Calculated in this case according to the equaticn of balance (7-02) final enthalpy and temperature of gases are accepted for the calculaticn following of the heating surface.

8-E. Calculation of the transient zone of single-pass boiler.

8-40. Enthalpy of steam-water mixture (cr steam) at entrance

into transition zone and steam at output/yield from it during rational design are prescribed/assigned. During the verifying calculation these enthalpy are received with these following as testing and their refinement.

To avoid the deposit of salts in the basic sections of the boiling and superheater heating surfaces humidity of steam at the entrance into transition zone must be not less than 15-20o/o, and superheating steam at the output/yield of it $t''-t_{\kappa.n}$ is not less than 20°C with all possible loads of boiler. In the presence of the separator before the transient zone the steam at the entrance into it is received as dry.

8-41. Calculation of convective transient zone of single-pass boiler does not differ from calculation of convective superheater with high humidity of that coming it steam, i.e. with steam cooler on side of saturated steam. However, taking into account low superheating, it is possible with its value not higher than 40°C to design the temperature head for the entire transient zone as a mean arithmetic difference in the temperatures of gases and water during the boiling. If superheating steam in the transient zone is higher than 40°C, it is designed from the sections according to recommendations p. 7-68.

Heat-transfer coefficient from the wall to steam $\alpha_2$ is not considered in view of its high values.

8-42. Calculation of radiation transient zone does not differ from calculation of radiation superheater.

8-F. Calculation of economizer.

8-43. During rational design of economizer enthalpy of gases and water at entrance are known. The calculated heat absorption of economizer is determined from the equation of the balance

$$Q_{\text{эк}} = Q_p^p \eta_{\text{к.а}} \frac{100}{100 - q_4} - Q_л - Q_к - Q_{пе} \quad \text{kcal/kg} \qquad (8\text{-}15)$$

where $Q_л$, $Q_к$ and $Q_{пе}$ - quantities of heat, taken on 1 kg of fuel/propellant by the beam-receiving surfaces of heating, by boiler bundles and superheater, kcal/kg.

In the formula substitute the value themselves of heat absorptions, determined from the equations of balance.

During the verifying calculation the input enthalpy of gases and water also are usually known. The order of the verifying calculation of economizer see in paragraphs 8-05 and 8-06.

The calculation of the steps/stages of two-stage economizers in no way differs from the calculation of single-stage economizers.

8-44. Entire calculation of feed-water economizer in essence coincides with calculation of superheater. Drops out the determination of $\alpha_2$. Over-all heat-transfer coefficient is designed from formula (7-106).

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In the calculation of economizer are introduced the actual consumption of the water through it $D_{э}$ kg/h taking into account blasting and passage of the water through the steam cooler (upon the parallel connection of steam cooler and economizer), and also the actual enthalpy of water at the entrance into the economizer (with the return of water from the steam cooler into the economizer). The latter is determined from the formula

$$i' = i_{п.в} + \Delta i_{по} \frac{D_{пе}}{D_{эк}} \text{ kcal/kg}, \quad (8\text{-}16)$$

where i' and $i_{п.в}$ - enthalpy of water at the entrance into the economizer and feed water, kcal/kg; $\Delta i_{по}$ - drop/jump in the enthalpy of steam in the steam cooler, obtained from the calculation of superheater, kcal/kg; $D_{пе}$ - expenditure/consumption of steam through superheater, kg/h.

8-45. Temperature head in economizer is determined taking into account mutual direction of flows of gases and water. During the partial evaporation of water in the economizer the calculation of the temperature head is conducted according to the conditional temperature of water at the output/yield (see Section 7-69). By the same temperature is determined mean temperature of water for calculating the temperature of wall.

8-46. Temperature of contaminated wall of feed-water economizer is located through indications p. 7-38.

8-47. In presence of bypass flue part of the gas through leakages/loosenesses in shutters/valves is passed by economizer. For the double closed dampers this part takes as the equal to 5, for the single ones - 10o/o. The determination of the temperature of gases at exit from economizer and gas velocity is produced taking into account the passage of part of the gas across the shurt.

8-48. Coefficient of heat transfer of finned economizers TsKKB and VTI is determined on nomogram XVI. For the finned economizers of other types and fin economizers the coefficient of heat transfer is designed from the indications Section "g" § 7-B.

The surface of heating finned economizers is determined along

the gas side. For the economizers TsKKB and VTI the heating surface is accepted on nomogram XVI. The surface of heating fin econcmizers is determined taking intc account the surface of fins according to the formula

$$H = \pi d l_{mp} + 4 h_{n.s} l_{n.s}\ m^2. \qquad (8\text{-}17)$$

where $h_{n.s}$ and $l_{n.s}$ - height and length of fins, m.

8-G. Calculation of air preheater.

8-49. With single-stage layout air preheater is designed as one whole. With the layout "in series" each part cf the air preheater is designed separately. The procedures of calculation of entire air preheater and its parts are distinguished only by separate details; therefore they are stated together.

8-50. During rational design of air preheater are prescribed/assigned temperature of airs at the inlet into air preheater and output/yield frcm it, and also temperature of gases at one end.

During the verifying calculation are known the input enthalpy cf gases and air. Order of the verifying calculaticn of air preheater see paragraphs 8-05 and 8-06.

8-51. Balance of heat along gas and air sides of air preheater is reduced with the help of formulas (7-02) and (7-04).

In latter/last formula $\beta''_{вп}$ - the ratio of the air flow rate per output/yield from the air preheater to theoretically necessary.

Calculation is conducted according to the real air flow rate taking into account the suctions and the leakages in that following channel.

In the case of preheating of all the air in the air preheater value $\beta''_{вп}$ for the single-stage and the second step/stage of the two-stage of air preheaters is determined from the equality

$$\beta''_{вп} = \alpha_m - \Delta\alpha_m - \Delta\alpha_{пл.у}. \qquad (8\text{-}18)$$

where $\alpha_m$ - excess air ratio in the heating; $\Delta\alpha_m$ and $\Delta\alpha_{пл.у}$ - suctions of air in heating and system of the pulverized coal preparations, determined in accordance with the indications RN 4-06 and 4-07.

Value of $\beta''_1$ for first stage of two-stage air preheater is determined from the equality

$$\beta''_1 = \beta''_{вп} + \Delta\alpha_2, \qquad (8\text{-}19)$$

where $\Delta\alpha_2$ - air escape from secondary air heater, taken to the equal to suction along the gas side.

In the case of preheating in the second step/stage only of part of the air the calculaticn of this stage is conducted according to the actually outgoing frcm it quantity of air.

8-52. When temperature of air at the inlet into air preheater is raised due to recirculation of part of hot air, ratio of quantity of recirculating air to theoretically necessary is determined according to approximate equation

$$\beta_{\text{рц}} \approx (\beta''_{\text{вп}} + \Delta\alpha_{\text{вп}}) \frac{t'_{\text{вп}} - t_{\text{х.в}}}{t_{\text{г.в}} - t'_{\text{вп}}}. \quad (8\text{-}20)$$

where $\Delta\alpha_{\text{вп}}$ - air escape frcm air ducts in entire air preheater, taken to equal to suction alcng gas side; $t_{\text{х.в}}$, $t'_{\text{вп}}$ and $t_{\text{г.в}}$ - temperature of air, correspondingly, cold, at entrance into air preheater (after mixing of cold with recirculating) and fuel, that goes for recirculation, °C.

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In the presence of recirculation the balance of heat, the temperature head, mean temperature and air speed are designed on the real ones to flow rate and to temperatures of air. To value $\beta''_{\text{вп}}$ determined according tc formula (4-41), is added value $\beta_{\text{рц}}$.

8-53. Temperature head in air preheater is determined taking into account mutual direction of flows of gases and air.

8-54. Mean temperatures of gases and air are defined as half-sums of their inlet temperatures into air preheater and exit from it.

8-55. For lamellar air preheaters with rotation of air within cubes should be according to formula (7-22) averaged (over washed surfaces) section/cut of air ducts in individual sections. For it is earlier than the produced air preheaters of the type Zh and [illegible] the averaging of courses is excessive as a result of their practical equality in all three sections (upon the entrance, in turn and on leaving).

During the setting up of the tubular air preheaters of special types with the turn of flow in the limits of the bundle of the ducts (intermediate pipe panels do not reach boundary tubes of bundle) they are designed as bundles with mixed longitudinal-transverse flow.

8-56. Average/mean air speed is determined according to average/mean (between entrance and output/yield) air flow rate in examined step/stage:

$$w_{в} = \frac{\left(\beta'' + \beta_{рц} + \frac{\Delta\alpha}{2}\right) B_p V^0 (t_{в} + 273)}{3600 \cdot 273 f} \ m/s. \tag{8-21}$$

where $\beta''$ - ratio of quantity of air for output/yield from designed step/stage of air preheater to theoretically necessary; [illegible] - air escape from air side in designed step/stage, taken to equal to suction along gas side.

8-57. Convection heat-transfer coefficients from gases to wall and from wall to air are determined taking into account following positions.

For the tubular air preheaters the convection heat-transfer coefficient for the medium, which flows within the ducts, is determined on nomogram IV with the appropriate correction for the physical characteristics of medium and temperature conditions $c_\phi$. During cooling of gases in ducts $c_\phi$ it does not depend on the temperature of wall. During heating of air in ducts $c'_\phi$ it depends on the temperature of wall, taken the equal half-sum of mean temperatures of gases and air. Correction for relative length ducts usually should not be considered.

For the medium, which moves between the ducts, the convection heat-transfer coefficient with the purely transverse flow is determined on nomogram III or II in depending on run of pipes in the bundle (checkered or corridor). With the mixed longitudinal-transverse flow is designed weighted mean in the

appropriate heating surfaces heat-transfer coefficient. Instructions on the introduction of correction $c_s$ for calculating longitudinal-washed sections - the same as for the case of course in the ducts.

For the lamellar air preheaters the convection heat-transfer coefficients from the gases to the wall and from the wall to the air at values of $Re<10 \cdot 10^3$ are determined on nomogram VII. In the number domain Re indicated the value of heat-transfer coefficient does not depend on the width of slot and is determined only in depending on speed and temperature of medium. The upper lines on the nomogram, on which is shown the width of slots, serve for the indication of the limit of the applicability of nomogram. If with the use of nomogram the VII point of intersection of the lines, which correspond to the temperature of medium and speed of its action, proves to be above line, designating arranged/located by width slot, nomogram VII is not applied and heat-transfer coefficient is defined on nomogram IV as with the common longitudinal flow (see indications in accordance with the tubular air preheaters).

For the finned and finned-serrated air preheaters of the produced at present constructions/designs the convection heat-transfer coefficient from the gases to the wall is determined on nomogram XVII, from the wall to the air - on nomogram XVIII. For the

platy air preheaters of the Kusin plant the heat-transfer coefficient from the gases to the wall and from the wall to the air is determined on nomogram XIX. For the finned air preheaters of nonstandard constructions/designs the convection heat-transfer coefficients are determined on the indications Section "g" of paragraph 7-B.

For the regenerative rotating air preheaters the convection heat-transfer coefficients are determined on nomogram VIII.

8-58. Radiation heat-transfer coefficient combustion products for air preheaters into calculation does not enter.

8-59. Coefficients of heat transfer for air preheaters in contrast to other heating surfaces are designed from formula (7-11) with the help of coefficients of use of heating surface. The latter are accepted on nomogram XII.

8-60. Surface of heating tubular air preheaters is determined by mean diameter of ducts. The surface of heating the lamellar air preheaters is identical from the gas and air sides. It is determined on the appropriate designed standards. For the finned and finned-serrated air preheaters into the calculation is introduced the full/total/complete heating surface from the gas side, determined for the produced at present constructions/designs on nomogram XVII. For the rotating regenerative air preheaters in the calculation is introduced the two-sided surface of packing.

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Applications/appendices.

Appendix I.

CONVENTIONAL DESIGNATICNS.

1. Table 1 gives basic reductions, accepted for indices.

Table 2 gives the conventional designations used in the text of Standards.

Since the given in Tables 1 and 2 conditional designations cannot encompass all enccuntered cases, are given below general/common/total indicaticns, which should be been guided when selecting of the conventicnal designations and indices.

2. For designation cf bases magnitude are used letters of Latin, Russian and Greek alphabets.

It follows as far as possible to avoid use/application cf one and the same designaticn (letter) for different values. Identical designations are allowed/assumed in those of the case when they took roct in different areas cf technology.

3. Enthalpy, heat capacities, volumes, quantities of heat, etc., in reference to 1 kg (nm') of working medium/propellant, are designated by lower-case letters; by capital letters are designated the same units, in reference to 1 kg ($Nm^3$) of fuel/propellant, and total, for example: enthalpy 1 kg of steam i kcal/kg, enthalpy of products of combustion 1 kg of fuel/propellant I kcal/kg, general/common/total heat absorption of designed surface of heating Q kcal/h.

4. For designation of difference in values both for local ones and for averaged values is applied greek letter Δ, set to the left of basic letter of designation of datum. For example, a drop/jump in the enthalpy of gases in air preheater $\Delta I_{вп}$.

5. Complicated indices, which consist of several separate ones, are furnished in following sequence: first index characterizes process or working body, by the second - equipment component. For example, heat-transfer coefficient from the wall to the steam, which takes place in the superheater, will be designated $\alpha_{2пе}$, if affiliation of datum $\alpha_2$ to the superheater must be reflected in the designation.

6. In expression, which represents product from series/row of values, which have identical indices, index it is placed only in latter/last factor of product. For example, the total heat capacity

of gases after economizer $Vc''_{эк}$.

7. Indices, as a rule, are placed to the right below from principal notation. The use/application of superscripts (they are placed also to the right) is allowed/assumed in the following cases:

a) when they relate to the mass of fuel/propellant, for example the humidity of propellant $W^{p}$;

b) with the designation of any value at the entrance or the output/yield from the equipment components - above are placed respectively one or double prime; for example, the temperature of the air before and after air preheater $t'_{вп}$, $t''_{вп}$.

c) when are indicated the theoretically necessary quantities - above are placed zero; for example, the theoretically necessary volume of air $V^{0}$.

8. In limits of calculation of this element/cell of aggregate/unit indices, which indicate element/cell, are not placed.

9. For designation of average/mean values of calculated ones magnitude, as a rule, additional indices are not introduced. For example, mean temperature of gases in air preheater $\vartheta_{вп}$.

The calculated value, obtained by the method of special averaging, it is noted by index cp. For example, average heat-transfer coefficient with complicated flow $\alpha_{cp}$.

Table 1. Reductions, accepted for the indices.

| (1) Наименование | (2) Индекс | (1) Наименование | (2) Индекс | (1) Наименование | (2) Индекс |
|---|---|---|---|---|---|
| 1. Элементы оборудования (3) | | 2. Рабочие тела (4) | | Холодный воздух (5) | х. в (6) |
| Топка (7) | (14) т | Топливо (8) | (9) тл | Зола (10) | зл (12) |
| (19) Экраны (водяные) | (20) э | Газообразное топливо (15) | г. тл (16) | Шлак (11) | шл (13) |
| (25) Котельный пучок (котел) | к (26) | Вода (жидкость) (21) | (22) ж | Унос (17) | ун (18) |
| (28) Перегреватель | пе (29) | Вода при температуре кипения (27) | кип (30) | Провал (23) | пр (24) |
| (32) Вторичный перегреватель | (33) вт. пе | Питательная вода (34) | п. в (35) | (31) 3. Прочие индексы | |
| (38) Экономайзер | эк (39) | Пар (независимо от состояния) (40) | (41) п | Первичный (36) | пер (37) |
| (44) Воздухоподогреватель | (45) вп | Насыщенный пар (48) | н. п (49) | Вторичный (42) | вт (43) |
| (46) Переходная зона прямоточных котлов | п. з (47) | Перегретый пар (53) | (54) п. п | Присос (воздуха) (50) | прс (51) |
| (57) Котельный агрегат | к. а (58) | Вторичный пар (59) | вт. п (60) | Рециркуляция (55) | рц (56) |
| (63) Экономайзер низкого давления | эк. н. д (64) | Продукты сгорания (газы) (66) | [illegible] (67) | Общий (61) | общ (62) |
| (70) Золоуловитель | (71) зу | Сухие дымовые газы | с. г | Максимальный (68) | макс |
| (75) Пылеприготовительная установка | пл. у (76) | Газы рециркуляции (72) | (73) рц | Минимальный | мин |
| | | Сушильный агент (77) | с. а | Эквивалентный (74) | э |
| | | Воздух (обычной влажности) (81) | в (82) | Приведенный | пр |
| | | Сухой воздух (87) | с. в (88) | Расчетный | р |
| | | | | Часовой | час |
| | | | | Секундный (89) | сек (90) |

Key: (1). Designation. (2). Index. (3). Equipment components. (4). Working bodies. (5). Cold air. (6). x. v. (7). Heating. (8). Fuel/propellant. (9). tl. (10). Ash. (11). Slag. (12). zl. (13). shl. (14). t. (15). Gaseous fuel. (16). g. tl. (17). Escape. (18). un. (19). Shields (water). (20). e. (21). Water (liquid). (22). zh. (23). Failure/dip/trough. (24). pr. (25). Boiler bundle (boiler). (26). k. (27). Water at boiling point. (28). Superheater. (29). pe. (30). kip. (31). Other indices. (32). Secondary superheater. (33). vt. pe. (34). Feed water. (35). p. v. (36). Primary. (37). per. (38). Economizer. (39). ek. (40). Steam (independent of state). (41). p. (42). Secondary. (43). vt. (44). Air-preheater. (45). vp. (46). Transition zone of single-pass boilers. (47). p. z. (48). saturated steam. (49). n. p. (50). Suction (air). (51). prs. (52). No Key. (53). superheated steam. (54). p. p. (55). Recirculation. (56). rts. (57). Boiler aggregate/unit. (58). k. a. (59). secondary steam. (60). vt. p. (61). General/common/total. (62). obshch. (63). Low-pressure economizer.

(64). ek n. d. (65). Combustion products (gases). (66). Dry flue gases. (67). g. (68). Maximum. (69). max. (70). Ash catcher. (71). zu. (72). Recirculation gases. (73). rts. (74). Equivalent. (75). Dust-preparatory installation. (76). pl. u. (77). Drying agent. (78). s. a. (79). Given. (80). p. (81). Air (common humidities). (82). v. (83). Calculated. (84). r. (85). Hour. (86). chas. (87). Dry air. (88). s. v. (89). Per-second. (90). s.

## Pages 65-69. Appendix 1. Conventional designations.

## Table 2. Enumeration of the principal notations.

| (1) Обозначение | (2) Размерность | (3) Наименование величины |
|---|---|---|
| | | (4) 1 Топливо и очаговые остатки |
| | | (5) *а) Твердое и жидкое топлива* |
| $W^p$ | % | (6) Содержание влаги общей |
| $A^p$ | % | (7) Зольность |
| $(CO_2)^p_к$ | % | (8) Содержание углекислоты карбонатов |
| $S^p_{об}$, $S^p_{ст}$, | % | Содержание серы общей, сульфатной, колчеданной, (9) органической |
| $S^p_к$, $S^p_{ор}$ | % | |
| $C^p$, $H^p$, | % | (11) Содержание углерода, водорода, азота, кислорода |
| $N^p$, $O^p$ | | |
| $Q^p_б$, $Q^p_в$, $Q^p_н$ | (12) *ккал/кг* | (13) Теплоты сгорания по калориметрической бомбе, высшая и низшая |
| $V^г$ | % | (14) Выход летучих (на горючую массу) |
| $A^п = \frac{A^p}{Q^p_н} 1\,000$ | (15) %/тыс. *ккал/кг* | (16) Приведенная зольность топлива |
| $W^п = \frac{W^p}{Q^p_н} 1\,000$ | (15) %/тыс. *ккал/кг* | (17) Приведенная влажность топлива |
| $R_{88}$, $R_{200}$ | % | (18) Остаток пыли на сите с отверстиями размером 88 и 200 *мкн* |
| $Г_{ун}$, $Г_{шл+пр}$ | % | (19) Содержание горючих в уносе, шлаке и провале |
| $a_{ун}$, $a_{шл+пр}$ | | (20) Доля золы топлива в уносе, шлаке и провале |
| $B$ | (21) *кг/час* | (22) Часовой расход топлива |
| $B_p$ | • | Расчетный часовой расход топлива с поправкой на ме-(23)ханическую неполноту сгорания |
| $g$ | — | Весовая доля одного вида топлива в смеси топлив (24)(снабжается индексом, обозначающим топливо) |
| $q$ | — | Доля одного из топлив по тепловыделению в смеси (25) топлив (снабжается индексом, обозначающим топливо) |
| | | b (26) *б) Газообразное топливо* |
| $d_{г.тл}$ | (27) *г/нм³* | Содержание влаги в газообразном топливе (на 1 *нм³* (28) сухого газа) |
| $A^c_{г.тл}$ | % | Содержание минеральных примесей в газообразном (29) топливе (% по весу) |
| $Q^p_н$ | (30) *ккал/нм³* | Теплота сгорания 1 *нм³* сухого газа (31) |
| $\gamma^c_{г.тл}$ и and $\gamma^в_{г.тл}$ | (32) *кг/нм³* | Удельные веса сухого и влажного газообразного топ-(33) лива |

(10) На рабочую массу[1]

cont.

(34) 2. Воздух и продукты сгорания

(35) а) Вес и объем на 1 кг твердого и жидкого топлива или на 1 $нм^3$ газообразного топлива

| | | |
|---|---|---|
| $V^0$ | (36) $нм^3/кг$ (37) $нм^3/нм^3$ | Теоретически необходимый для сгорания объем воздуха (38) |
| $V^0_{N_2}$ | • | Теоретический объем азота (при $\alpha = 1$) (39) |
| $V_{RO_2}$ | • | Суммарный объем углекислоты $CO_2$ и сернистого газа $SO_2$ (40) |
| $V^0_г$ | • | Объем продуктов сгорания при $\alpha = 1$ (41) |
| $V_г$ | • | Полный объем продуктов сгорания (42) |
| $V_{рц}$ | (32) • | Объем газов, отбираемых для рециркуляции (43) |
| $\gamma_{с.в}$ and $\gamma_в$ | $кг/нм^3$ | Удельные веса сухого и влажного воздуха (44) |
| $r_{RO_2}$, $r_{H_2O}$ и $r_п$ | — | Объемные доли сухих трехатомных газов, водяных паров и суммарная (45) |
| $p_п$ | (45a) ата | Суммарное парциальное давление трехатомных газов (46) |
| $\mu$ | (31) $г/нм^3$ | Концентрация золы в продуктах сгорания (47) |
| $d_в$ and $d_г$ | (48) г/кг | Влагосодержания на 1 кг сухого воздуха и газов (49) |

(50) б) Теплоемкости и теплосодержания

| | | |
|---|---|---|
| $c_{CO_2}$ and $c_{H_2O}$ | (51) $ккал/нм^3$ град | Теплоемкости углекислоты и водяных паров (52) |
| $c_в$ | • | Теплоемкость влажного воздуха (при расчете на 1 $нм^3$ сухого) (53) |
| $Vc$ | (54) ккал/кг град | Суммарная теплоемкость продуктов сгорания (55) |
| $c_{зл}$ and $c_{тл}$ | (13) • | Теплоемкости золы и топлива (56) |
| $I$ | ккал/кг (30) $ккал/нм^3$ | Теплосодержание продуктов сгорания 1 кг или 1 $нм^3$ топлива (57) |
| $I^0_г$ | • | Теплосодержание продуктов сгорания 1 кг ($нм^3$) топлива при $\alpha = 1$ (58) |
| $I^0_в$ | • | Теплосодержание воздуха, теоретически необходимого для сгорания (59) |
| $I_в$ | • | Теплосодержание воздуха на 1 кг ($нм^3$) топлива (60) |
| $i_{тл}$ | • | Физическое тепло топлива (61) |

(62) c) Коэффициент избытка воздуха

| | | |
|---|---|---|
| $\alpha_т$ and $\alpha_{пе}$ | — | Коэффициенты избытка воздуха в топке и перед перегревателем (63) |
| $\Delta\alpha_т$ and $\Delta\alpha_{пе}$ | — | Присосы воздуха в газоходах (топке и перегревателе) (64) |
| $\Delta\alpha_{пл.у}$ | — | Присос воздуха в пылеприготовительной установке (65) |
| $\beta'_{вп}$ and $\beta''_{вп}$ | — | Отношения количества воздуха на входе в воздухоподогреватель и выходе из него к теоретически необходимому (66) |
| $\beta_{рц}$ | — | Отношение количества воздуха, рециркулирующего в воздухоподогревателе, к теоретически необходимому (67) |
| $g_ш$ | — | Количество газов, шунтирующих газоход, в долях начального количества (68) |

cont.

2. Физические характеристики (69)

| | | |
|---|---|---|
| $\mu$ | (70) $кг\ сек/м^2$ | Коэффициент динамической вязкости (71) |
| $\nu = \frac{\mu}{\rho}$ | (72) $м^2/сек$ | (73) Коэффициент кинематической вязкости при давлении 1 *ата* |
| $\nu_г$ | • | Коэффициент кинематической вязкости продуктов (74) сгорания среднего состава ($r_{CO_2} = 0,13$; $r_{H_2O} = 0,11$) при 1 *ата* |
| $\lambda_г$ | (75) $ккал/м\ час\ град$ | Коэффициент теплопроводности продуктов сгорания (76) среднего состава ($r_{CO_2} = 0,13$; $r_{H_2O} = 0,11$) |
| $\rho$ | (77) $кг\ сек^2/м^4$ | Плотность (78) |
| $\gamma$ | (79) $кг/м^3$ | Удельный вес (80) |
| $\gamma^0$ | (13) $кг/нм^3$ | Удельный вес при 0° C и 760 *мм рт. ст.* (81) |
| $a = \frac{\lambda}{c_p \gamma}$ | (82) $м^2/час$ | Коэффициент температуропроводности ($c_p$ — истин-(83)ная теплоемкость при постоянном давлении, *ккал/кг град*). |

(84)

3. Тепловой баланс, количества тепла и тепловые нагрузки

| | | |
|---|---|---|
| $\eta_{к.а}$ | % (12) | Коэффициент полезного действия (к. п. д.) котельного (85) агрегата (брутто) |
| $Q_1$; $q_1$ | *ккал/кг*; % | Полезно используемое тепло (86) |
| $Q_2$; $q_2$ | • • | Потеря тепла с уходящими газами (87) |
| $Q_3$; $q_3$ | • • | Потеря тепла от химической неполноты сгорания (88) |
| $Q_4$; $q_4$ | • • | Потеря тепла от механической неполноты сгорания (89) |
| $Q_{4шл+пр}$; $Q_{4ун}$; $q_{4шл+пр}$; $q_{4ун}$ | • • | Потери тепла с уносом, шлаком и провалом вслед-(90)ствие механической неполноты сгорания |
| $Q_5$; $q_5$ | • • | Потеря тепла в окружающую среду (91) |
| $Q_{6шл}$; $q_{6шл}$ | • • | Потеря с физическим теплом шлака (92) |
| $Q_{6охл}$; $q_{6охл}$ | • • | Потеря с водой, охлаждающей панели (93) |
| $\varphi$ | (94a) — | Коэффициент сохранения тепла (94) |
| $Q^р_р$ | *ккал/кг*, *ккал/нм³* | Располагаемое тепло на 1 *кг* (*нм³*) топлива (95) |
| $Q_в$ | • • | Тепло воздуха, поступающего в топку (96) |
| $Q_л$ | • • | Количество тепла, переданного поверхности нагрева излучением (97) |
| $\frac{Q}{V} = \frac{BQ^р_н}{V_т}$ | (98) $ккал/м^3\ час$ | Видимая тепловая нагрузка топочного объема (99) |
| $\frac{Q}{R} = \frac{BQ^р_н}{R}$ | (100) $\frac{ккал}{м^2 час}$ | (101) Видимая тепловая нагрузка колосниковой решетки (102) |

(103)

4. Вода и пар

| | | |
|---|---|---|
| $D$ | *кг/час*, *т/час* | Паропроизводительность котла (104) |
| $D_н$ | • • | Количество насыщенного пара, отданного котлом помимо перегревателя (105) |
| $D_{пр}$ | • • | Количество воды, идущее в продувку (106) |
| $D_{пе}$ | • • | Расход пара через перегреватель (107) |
| $D_{эк}$ | • (13) • | Расход воды через экономайзер (108) |
| $i_{п.п}$; $i_{н.п}$ | *ккал/кг* | Теплосодержания перегретого и насыщенного пара (109) |

cont.

| | | |
|---|---|---|
| $i_{п.в}$ | (12) ккал/кг | Теплосодержание питательной воды (110) |
| $i_{кип}$ | " | Теплосодержание воды при кипении (111) |
| $r$ | " | Теплота парообразования (112) |
| $\Delta i_{по}$ | " | Снижение теплосодержания пара в пароохладителе (113) |
| $i'$ and $i''$ | " (115) | Теплосодержания пара (воды) на входе в поверхность нагрева и выходе из нее (114) |
| | 5. Температуры и давления (116) | |
| $\vartheta_a$ | °C | Теоретическая (адиабатическая) температура сгорания |
| $\vartheta''_т$ and $\vartheta'_к$ | " | Температура на выходе из топки и входе в пучок (117) |
| $\vartheta_{ух}$ | " | Температура уходящих газов (118) |
| $t_{х.в}$ | " | Температура холодного, присосанного воздуха (119) |
| $t'_{вп}$ and $t''_{вп}$ | " | Температура воздуха на входе в воздухоподогреватель и выходе из него (120) |
| $t'_{эк}$ and $t''_{эк}$ | " | Температура воды на входе в экономайзер и выходе из него (121) |
| $t_{п.в}$ | " | Температура питательной воды (122) |
| $t_{п.п}$ | " | Температура перегретого пара (123) |
| $t'_{пе}$ and $t''_{пе}$ | " | Температура пара на входе в перегреватель и выходе из него (124) |
| $t_з$ | " | Температура наружной поверхности загрязнений (125) |
| $t^н_{ст}$ | " | Температура поверхности металла труб (126) |
| $\Delta t_б$ and $\Delta t_м$ | " | Большее и меньшее значения температурных напоров на границах рассматриваемой поверхности нагрева (127) |
| $\Delta t$ | " | Средний температурный напор (128) |
| $\tau$ | (45a) " | Перепад температур одного из теплоносителей (129) |
| $p_{изб}$ | ати | Избыточное (манометрическое) давление (130) |
| $p$ | (45b) ата | Абсолютное давление (131) |
| | 6. Теплопередача (132) | |
| $k_г$ | — | Коэффициент ослабления лучей трехатомными газами (133) |
| $k_п$ | — | Коэффициент ослабления лучей в объеме, заполненном пылью (134) |
| $a_ф$ | — | Эффективная степень черноты факела (135) |
| $a_т$ | (137) — | Степень черноты топки (136) |
| $\alpha_л$ | ккал/м² час град | Коэффициент теплоотдачи межтрубным излучением продуктов сгорания (138) |
| $\alpha_{л.г}$ | " | Коэффициент теплоотдачи межтрубным излучением трехатомных газов (139) |
| $\alpha_к$ | " | Коэффициент теплоотдачи конвекцией (140) |
| $\alpha_1$ | " | Суммарный коэффициент теплоотдачи от газов к стенке (141) |
| $\alpha_2$ | " | Коэффициент теплоотдачи от стенки к теплоносителю (142) |
| $\omega$ | " | Коэффициент омывания (143) |

cont.

| (144) | | (145) |
|---|---|---|
| $\varepsilon$ | $м^2$ час град/ккал | Коэффициент теплового сопротивления слоя внешних загрязнений (коэффициент загрязнения) |
| $\xi$ | (137) — | Коэффициент использования поверхности нагрева (146) |
| $k$ | ккал/$м^2$ час град | Коэффициент теплопередачи (147) |
| $w$ | (148) м/сек | Скорость газов (149) |
| $Re = \frac{wl}{\nu}$ | — | Критерий Рейнольдса ($l$ — определяющий линейный размер) (150) |
| $Pr = 3600\frac{\nu}{a}$ | — | Критерий физических свойств среды (151) |
| $Nu = \frac{\alpha l}{\lambda}$ | — | Критерий Нуссельта (152) |
| | (153) 7. Геометрические характеристики | |
| $V_m$ | $м^3$ | Объем топочной камеры (154) |
| $R$ | $м^2$ | Площадь зеркала горения (155) |
| $H$ | • | Поверхность нагрева (индекс внизу—наименование поверхности) (156) |
| $F_{ст}$ | • | Поверхность стен (157) |
| $x$ | — | Угловой коэффициент (158) |
| $\psi$ | — | Степень экранирования топки (159) |
| $\zeta$ | — | Условный коэффициент загрязнения лучевоспринимающих поверхностей (160) |
| $H_л$ | $м^2$ | Лучевоспринимающая поверхность (161) |
| $s$ | $м$ | Эффективная толщина газового слоя (162) |
| $d$ and и $d_{вн}$ | мм, м | Наружный и внутренний диаметры (163) |
| $d_э$ | • • | Эквивалентный диаметр (164) |
| $s_1$; $s_2$ and и $s_2'$ | • • | Поперечный, продольный и диагональный шаги труб (165) |
| $F$ и $f$ | $м^2$ | Живое сечение для прохода газов и пара (воды) (166) |
| $H_{поп}$ and и $H_{пр}$ | • | Части поверхности нагрева, омываемые поперечным и продольным потоками (167) |
| $F_{поп}$ and и $F_{пр}$ | • | Живые сечения для поперечного и продольного потоков (168) |

Key: (1). Designation. (2). Dimensionality. (3). Designation of value. (4). Fuel/propellant and clinkers. (5). Solid and liquid propellants. (6). Moisture content of general/common/total. (7). Ash content. (8). Content cf carbcnic acid of carbonates. (9). Content of

sulfur general/common/total, sulfate, pyritic, organic. (10). To working mass [1].

FOOTNOTE [1]. For the designation of the elementary propellant composition, in reference to other masses, are used the same basic letters and subscripts. Change only respectively superscripts, namely: for the analytical mass - index a; for the dry mass - index s; for the combustible mass - index g. ENDFOOTNOTE.

(11). Carbon content, hydrogen, nitrogen, oxygen. (12). kcal/kg. (13). Heat of combustions on calorimeter, highest and lowest. (14). output/yield of volatile components (to combustible mass). (15). thousand of kcal/kg. (16). Given ash content of fuel/propellant. (17). Given humidity of fuel/propellant. (18). Remainder/residue of dust on sieve with holes by size/dimension 88 and 200 microns. (19). Content of fuels in escape, slag and failure/dip/trough. (20). Share of ash of fuel/propellant in escape, slag and failure/dip/trough. (21). kg/h. (22). Hourly consumption of fuel/propellant. (23). Calculated hourly consumption of fuel/propellant with correction for mechanical incompleteness of combustion. (24). Part by weight of one form of fuel/propellant in mixture of fuels/propellants (it is supplied with index, which designates fuel/propellant). (25). Fraction/portion of one of fuels/propellants on heat release in mixture of fuels/propellants (it is supplied with index, which

designates fuel/propellant). (26). Gaseous fuel. (27). g/nm³. (28). Moisture content in gasecus fuel (cn 1 nm³ cf dry gas). (29). Content of mineral admixtures/impurities in gaseous fuel (o/o by weight). (30). kcal/nm³. (31). Heat of combustion 1 nm³ of dry gas. (32). kg/nm³. (33). Specific gravity/weights of dry and humid gaseous fuel. (34). Air and combusticn products. (35). Weight and volume on 1 kg of solid and liquid propellants or on 1 nm³ of gaseous fuel. (36). nm³/kg. (37). nm³/nm³. (38). Theoretically necessary for combustion volume of air. (39). Theoretical volume of nitrogen (with $\alpha=1$). (40). Total volume of carbonic acid $CO_2$ and sulfur dioxide $SO_2$. (41). Volume of combustion products with $\alpha=1$. (42). Full/total/complete volume of combustion products. (43). Volume of gases, selected/taken for recirculation. (44). Specific gravity/weights of dry and humid air. (45). Volume fractions of dry triatomic gases, water vapors and total. (45a). atm(abs.). (46). Total partial pressure of triatomic gass. (47). Ash concentration in combustion products. (48). g/kg. (49). Moisture contents on 1 kg of dry air and gases. (50). Heat capacities and enthalpy. (51). kcal/nm³ deg. (52). Heat capacities of carbonic acid and water vapors. (53). Heat capacity of humid air (during calculation on 1 nm³ of dry). (54). kcal/kg deg. (55). Total heat capacity of combustion products. (56). Heat capacities of ash and fuel/propellant. (57). Enthalpy of combustion products 1 kg or 1 nm³ of fuel/propellant. (58). Enthalpy of products of combustion 1 kg (nm³) of fuel/propellant with $\alpha=1$. (59). Enthalpy of air,

theoretically necessary for combustion. (60). Enthalpy of air on 1 kg ($nm^3$) of fuel/propellant. (61). Physical heat of fuel/propellant. (62). Excess air ratio. (63). Excess air ratios in heating and before superheater. (64). Suctions of air in flues (heating and superheater). (65). Suction of air in dust-preparatory installation. (66). Ratios of quantity of air at entrance into air preheater and output/yield from it to theoretically necessary. (67). Ratio of quantity of air, which recirculates in air preheater, to theoretically necessary. (68). Quantity of gases, which shunt flue, in fractions of initial quantity. (69). Physical characteristics. (70). kg $s/m^2$. (71). Coefficient of dynamic viscosity. (72). $m^2/s$. (73). Kinematic viscosity coefficient at pressure 1 atm(abs.). (74). Kinematic viscosity coefficient of combustion products of average/mean composition ($r_{CO_2}$ =0.13; $r_{H_2O}$ =0.11) with 1 atm(abs.). (75). kcal/m hour deg. (76). Coefficient of thermal conductivity of combustion products of average/mean composition ($r_{CO_2}$ =0.13; $r_{H_2O}$ =0.11). (77). kg $s^2/m^4$. (78). Density. (79). $kg/m^3$. (80). Specific gravity/weight. (81). Specific gravity/weight with 0°C and 760 mm Hg. (82). $m^2/h$. (83). Coefficient of thermal diffusivity ($c_p$ - true heat capacity at constant pressure, kcal/kg deg). (84). Heat balance, quantities of heat and thermal loads. (85). Efficiency of boiler aggregate/unit (gross weight). (86). Usefully utilized heat. (87). Heat loss with stack gases. (88). Heat loss from chemical incompleteness of combustion. (89). Heat loss from mechanical

incompleteness of combustion. (90). Heat losses with escape, slag and failure/dip/trough as a result of mechanical incompleteness of combustion. (91). Heat loss into environment. (92). Loss with physical heat of slag. (93). Loss with water, cooling panel. (94). Coefficient of retention/preservation/maintaining heat. (94a). kcal/kg, kcal/nm³. (95). Available heat on 1 kg (nm³) of fuel/propellant. (96). Heat of air, which enters heating. (97). Quantity of heat, transmitted to heating surface by radiation/emission. (98). kcal/m³ hour. (99). Visible thermal load of furnace cavity. (100). kcal/m² hour. (101). Visible thermal load of fire grate. (102). Water and steam. (103). kg/h, m/h. (104). Boiler steam capacity. (105). Quantity of saturated steam, returned by boiler besides superheater. (106). Quantity of water, which goes into blasting. (107). Flow rate of steam through superheater. (108). Flow rate of water through economizer. (109). Enthalpy of overheated and saturated steam. (110). Enthalpy of feed water. (111). Enthalpy of water during boiling. (112). Heat of vaporization. (113). Reduction in enthalpy of steam in steam cooler. (114). Enthalpy of steam (water at entrance into heating surface and output/yield from it. (115). Temperatures and pressure. (116). Theoretical (adiabatic) temperature of combustion. (117). Outlet temperature from heating and entrance into bundle. (118). Temperature of stack gases. (119). Temperature of cold, sucked air. (120). Temperature of air at the inlet into air preheater and output/yield from it. (121). Temperature of water at

entrance into economizer and output/yield from it. (122). Temperature of feed water. (123). Temperature of superheated steam. (124). Temperature of steam at entrance into superheater and output/yield from it. (125). Temperature of external surface of pollution/contamination. (126). Temperature of surface of metal of ducts. (127). Is greater and smaller value of temperature heads on boundaries/interfaces of heating surface in question. (128). Average/mean temperature head. (129). Temperature differential of one of heat-transfer agents. (130). Excess (manometric) pressure. (131). Absolute pressure. (132). Heat transfer. (133). Coefficient of weakening rays/beams by triatomic gases. (134). Coefficient of weakening rays/beams in volume, filled with dust. (135). Efficient emissivity factor of flame. (136). Emissivity factor of heating. (137). kcal/m² hour deg. (138). Heat-transfer coefficient by intertube radiation/emission of combustion products. (139). Heat-transfer coefficient by intertube radiation/emission of triatomic gases. (140). Convection heat-transfer coefficient. (141). Total heat-transfer coefficient from gases to wall. (142). Heat-transfer coefficient from wall to heat-transfer agent. (143). Coefficient of flow. (144). m² hour deg/kcal. (145). Coefficient of thermal resistance of layer of external of contamination (contamination factor). (146). Coefficient of use of heating surface. (147). Coefficient of heat transfer. (148). m/s. (149). Gas velocity. (150). Reynolds number (l - determining linear dimension). (151).

Criterion of physical properties of medium. (152). Nusselt's criterion. (153). Geometric characteristics. (154). Volume of furnace chamber/camera. (155). Area of mirror of combustion. (156). Surface of heating (subscript - designation of surface). (157). Surface of walls. (158). Angular coefficient. (159). Degree of shielding of heating. (160). Conditional contamination factor of beam-receiving surfaces. (161). Beam-receiving surface. (162). Efficient thickness of gas layer. (163). External and internal diameter. (164). Equivalent diameter. (165). Transverse, longitudinal and diagonal spacers of ducts. (166). Clear opening for pass of gases and steam (water). (167). Parts of heating surface, washed by transverse and longitudinal flows. (168). Clear openings for transverse and longitudinal flows.

Appendix II.

TABLES OF ENTHALPY AND SPECIFIC VOLUMES OF WATER AND WATER VAPOR.

The values of specific volumes and enthalpy of water and water vapor are given on the tables VII the "Thermophysical properties of substances", handbook, edited by N. B. Vargaftik, Gosenergoizdat, 1956.

Volume and order of the arrangement/position of data in the tables correspond to the requirements of the execution of the thermal designs of boiler aggregates/units.

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A. Dry saturated vapor and water on saturation curve.

| atm. (abs.) p | t, °C | $m^3$/kg v' | $m^3$/kg v'' | kcal/kg i' | kcal/kg i'' | kcal/kg r |
|---|---|---|---|---|---|---|
| 0,010 | 6,698 | 0,0010001 | 131,7 | 6,73 | 600,2 | 593,5 |
| 0,020 | 17,204 | 0,0010013 | 68,26 | 17,25 | 604,9 | 587,6 |
| 0,030 | 23,772 | 0,0010027 | 46,52 | 23,80 | 607,8 | 584,0 |
| 0,040 | 28,641 | 0,0010041 | 35,46 | 28,67 | 609,8 | 581,1 |
| 0,050 | 32,55 | 0,0010053 | 28,73 | 32,58 | 611,5 | 578,9 |
| 0,060 | 35,82 | 0,0010064 | 24,18 | 35,84 | 613,0 | 577,2 |
| 0,070 | 38,66 | 0,0010074 | 20,92 | 38,67 | 614,2 | 575,5 |
| 0,080 | 41,16 | 0,0010084 | 18,45 | 41,17 | 615,2 | 574,0 |
| 0,090 | 43,41 | 0,0010093 | 16,51 | 43,41 | 616,1 | 572,7 |
| 0,10 | 45,45 | 0,0010101 | 14,95 | 45,45 | 617,0 | 571,6 |
| 0,12 | 49,06 | 0,0010116 | 12,59 | 49,05 | 618,6 | 569,5 |
| 0,14 | 52,18 | 0,0010130 | 10,88 | 52,17 | 619,9 | 567,7 |
| 0,16 | 54,94 | 0,0010144 | 9,604 | 54,92 | 621,1 | 566,2 |
| 0,18 | 57,41 | 0,0010157 | 8,600 | 57,40 | 622,1 | 564,7 |
| 0,20 | 59,67 | 0,0010169 | 7,789 | 59,65 | 623,0 | 563,4 |
| 0,22 | 61,74 | 0,0010181 | 7,123 | 61,71 | 623,9 | 562,2 |
| 0,24 | 63,65 | 0,0010191 | 6,564 | 63,63 | 624,7 | 561,1 |
| 0,26 | 65,44 | 0,0010201 | 6,082 | 65,45 | 625,4 | 560,0 |
| 0,28 | 67,11 | 0,0010211 | 5,680 | 67,09 | 626,1 | 559,0 |
| 0,30 | 68,68 | 0,0010221 | 5,324 | 68,66 | 626,7 | 558,0 |
| 0,40 | 75,42 | 0,0010261 | 4,066 | 75,41 | 629,5 | 554,1 |
| 0,50 | 80,86 | 0,0010296 | 3,299 | 80,86 | 631,6 | 550,7 |
| 0,60 | 85,45 | 0,0010327 | 2,781 | 85,47 | 633,5 | 548,0 |
| 0,70 | 89,45 | 0,0010355 | 2,409 | 89,49 | 635,1 | 545,6 |
| 0,80 | 92,99 | 0,0010381 | 2,126 | 93,05 | 636,4 | 543,4 |
| 0,90 | 96,18 | 0,0010405 | 1,904 | 96,25 | 637,6 | 541,3 |
| 1,0 | 99,09 | 0,0010428 | 1,725 | 99,18 | 638,7 | 539,5 |
| 1,5 | 110,79 | 0,0010521 | 1,180 | 110,99 | 643,1 | 532,1 |
| 2,0 | 119,62 | 0,0010600 | 0,9019 | 119,94 | 646,3 | 526,4 |
| 2,5 | 126,79 | 0,0010666 | 0,7319 | 127,3 | 648,7 | 521,4 |
| 3,0 | 132,88 | 0,0010726 | 0,6160 | 133,5 | 650,8 | 517,3 |
| 3,5 | 138,19 | 0,0010780 | 0,5338 | 138,9 | 652,4 | 513,5 |
| 4,0 | 142,92 | 0,0010829 | 0,4708 | 143,7 | 653,9 | 510,2 |
| 4,5 | 147,20 | 0,0010875 | 0,4215 | 148,1 | 655,2 | 507,1 |
| 5,0 | 151,11 | 0,0010918 | 0,3818 | 152,1 | 656,3 | 504,2 |
| 6,0 | 158,08 | 0,0011000 | 0,3214 | 159,4 | 658,3 | 498,9 |
| 7,0 | 164,17 | 0,0011071 | 0,2778 | 165,7 | 659,9 | 494,2 |
| 8,0 | 169,61 | 0,0011140 | 0,2448 | 171,4 | 661,2 | 489,8 |
| 9,0 | 174,53 | 0,0011202 | 0,2190 | 176,5 | 662,3 | 485,8 |
| 10,0 | 179,04 | 0,0011262 | 0,1980 | 181,2 | 663,3 | 482,1 |
| 11,0 | 183,20 | 0,0011318 | 0,1808 | 185,7 | 664,1 | 478,4 |
| 12,0 | 187,08 | 0,0011372 | 0,1663 | 189,8 | 664,9 | 475,1 |
| 13,0 | 190,71 | 0,0011425 | 0,1540 | 193,6 | 665,6 | 472,0 |
| 14,0 | 194,13 | 0,0011475 | 0,1434 | 197,3 | 666,2 | 468,9 |
| 15,0 | 197,36 | 0,0011524 | 0,1342 | 200,7 | 666,7 | 466,0 |
| 16,0 | 200,43 | 0,0011572 | 0,1261 | 204,0 | 667,1 | 463,1 |
| 17,0 | 203,35 | 0,0011618 | 0,1189 | 207,2 | 667,5 | 460,3 |
| 18,0 | 206,14 | 0,0011662 | 0,1125 | 210,2 | 667,8 | 457,7 |
| 19,0 | 208,81 | 0,0011707 | 0,1068 | 213,1 | 668,2 | 455,1 |
| 20,0 | 211,38 | 0,0011751 | 0,1016 | 215,9 | 668,5 | 452,6 |
| 21,0 | 213,85 | 0,0011794 | 0,09676 | 218,6 | 668,7 | 450,1 |
| 22,0 | 216,23 | 0,0011834 | 0,09244 | 221,3 | 668,9 | 447,6 |
| 23,0 | 218,53 | 0,0011874 | 0,08848 | 223,7 | 669,0 | 445,3 |
| 24,0 | 220,75 | 0,0011914 | 0,08486 | 226,2 | 669,2 | 443,0 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| 25,0 | 222,90 | 0,0011953 | 0,08150 | 228,6 | 669,3 | 440,7 |
| 26,0 | 224,99 | 0,0011992 | 0,07838 | 231,0 | 669,4 | 438,4 |
| 27,0 | 227,01 | 0,0012030 | 0,07550 | 233,2 | 669,4 | 436,2 |
| 28,0 | 228,98 | 0,0012067 | 0,07282 | 235,3 | 669,4 | 434,1 |
| 29,0 | 230,89 | 0,0012105 | 0,07032 | 237,5 | 669,5 | 432,0 |
| 30,0 | 232,76 | 0,0012142 | 0,06793 | 239,6 | 669,5 | 429,9 |
| 31,0 | 234,57 | 0,0012179 | 0,06570 | 241,7 | 669,5 | 427,8 |
| 32,0 | 236,35 | 0,0012215 | 0,06370 | 243,7 | 669,5 | 425,8 |
| 33,0 | 238,08 | 0,0012250 | 0,06176 | 245,6 | 669,5 | 423,9 |
| 34,0 | 239,77 | 0,0012285 | 0,05993 | 247,6 | 669,5 | 421,9 |
| 35,0 | 241,42 | 0,0012320 | 0,05819 | 249,5 | 669,5 | 420,0 |
| 36,0 | 243,04 | 0,0012355 | 0,05655 | 251,3 | 669,4 | 418,1 |
| 37,0 | 244,62 | 0,0012389 | 0,05499 | 253,1 | 669,3 | 416,2 |
| 38,0 | 246,17 | 0,0012424 | 0,05351 | 254,9 | 669,2 | 414,3 |
| 39,0 | 247,69 | 0,0012459 | 0,05211 | 256,6 | 669,1 | 412,5 |
| 40,0 | 249,18 | 0,0012493 | 0,05078 | 258,4 | 669,0 | 410,6 |
| 41,0 | 250,64 | 0,0012527 | 0,04950 | 260,1 | 668,9 | 408,8 |
| 42,0 | 252,07 | 0,0012561 | 0,04828 | 261,8 | 668,8 | 407,0 |
| 43,0 | 253,48 | 0,0012595 | 0,04712 | 263,5 | 668,7 | 405,2 |
| 44,0 | 254,87 | 0,0012629 | 0,04601 | 265,1 | 668,5 | 403,4 |
| 45,0 | 256,23 | 0,0012663 | 0,04495 | 266,7 | 668,4 | 401,7 |
| 46,0 | 257,56 | 0,0012696 | 0,04394 | 268,2 | 668,2 | 400,0 |
| 47,0 | 258,88 | 0,0012729 | 0,04297 | 269,7 | 668,0 | 398,3 |
| 48,0 | 260,17 | 0,0012762 | 0,04203 | 271,3 | 667,9 | 396,6 |
| 49,0 | 261,45 | 0,0012794 | 0,04113 | 272,8 | 667,7 | 394,9 |
| 50,0 | 262,70 | 0,0012826 | 0,04026 | 274,3 | 667,5 | 393,2 |
| 52,0 | 265,15 | 0,0012890 | 0,03862 | 277,2 | 667,1 | 389,9 |
| 54,0 | 267,53 | 0,0012954 | 0,03711 | 280,1 | 666,7 | 386,6 |
| 56,0 | 269,84 | 0,0013018 | 0,03569 | 282,9 | 666,3 | 383,4 |
| 58,0 | 272,10 | 0,0013083 | 0,03436 | 285,7 | 665,9 | 380,2 |
| 60,0 | 274,29 | 0,0013147 | 0,03312 | 288,4 | 665,4 | 377,0 |
| 62,0 | 276,43 | 0,0013211 | 0,03197 | 291,0 | 664,8 | 373,8 |
| 64,0 | 278,51 | 0,0013275 | 0,03088 | 293,6 | 664,3 | 370,7 |
| 66,0 | 280,55 | 0,0013339 | 0,02986 | 296,1 | 663,7 | 367,6 |
| 68,0 | 282,54 | 0,0013402 | 0,02889 | 298,6 | 663,2 | 364,6 |
| 70,0 | 284,48 | 0,0013466 | 0,02798 | 301,0 | 662,6 | 361,6 |
| 72,0 | 286,39 | 0,0013530 | 0,02711 | 303,5 | 661,9 | 358,4 |
| 74,0 | 288,25 | 0,0013594 | 0,02628 | 305,9 | 661,3 | 355,4 |
| 76,0 | 290,08 | 0,0013658 | 0,02551 | 308,2 | 660,7 | 352,5 |
| 78,0 | 291,86 | 0,0013722 | 0,02476 | 310,5 | 660,0 | 349,5 |
| 80,0 | 293,62 | 0,0013787 | 0,02405 | 312,8 | 659,4 | 346,6 |
| 82,0 | 295,34 | 0,0013852 | 0,02338 | 315,1 | 658,7 | 343,6 |
| 84,0 | 297,03 | 0,0013918 | 0,02273 | 317,3 | 657,9 | 340,6 |
| 86,0 | 298,69 | 0,0013984 | 0,02212 | 319,5 | 657,1 | 337,6 |
| 88,0 | 300,32 | 0,0014049 | 0,02153 | 321,6 | 656,4 | 334,8 |
| 90,0 | 301,92 | 0,0014115 | 0,02097 | 323,8 | 655,7 | 331,9 |
| 92,0 | 303,49 | 0,0014181 | 0,02043 | 326,0 | 655,0 | 329,0 |
| 94,0 | 305,04 | 0,0014249 | 0,01991 | 328,1 | 654,2 | 326,1 |
| 96,0 | 306,56 | 0,0014317 | 0,01941 | 330,2 | 653,4 | 323,2 |
| 98,0 | 308,06 | 0,0014384 | 0,01892 | 332,3 | 652,6 | 320,3 |
| 100,0 | 309,53 | 0,0014453 | 0,01846 | 334,3 | 651,7 | 317,4 |
| 102,0 | 310,98 | 0,0014523 | 0,01802 | 336,3 | 650,8 | 314,5 |
| 104,0 | 312,41 | 0,0014591 | 0,01759 | 338,3 | 649,9 | 311,6 |
| 106,0 | 313,82 | 0,0014661 | 0,01717 | 340,3 | 649,0 | 308,7 |
| 108,0 | 315,21 | 0,0014732 | 0,01677 | 342,3 | 648,1 | 305,8 |
| 110,0 | 316,58 | 0,001481 | 0,01638 | 344,2 | 647,1 | 302,9 |
| 112,0 | 317,93 | 0,001488 | 0,01600 | 346,2 | 646,2 | 300,0 |
| 114,0 | 319,26 | 0,001495 | 0,01564 | 348,2 | 645,3 | 297,1 |

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|---|---|---|---|---|---|---|
| 116,0 | 320,57 | 0,001502 | 0,01529 | 350,1 | 644,4 | 294,3 |
| 118,0 | 321,87 | 0,001510 | 0,01495 | 352,0 | 643,4 | 291,4 |
| 120,0 | 323,15 | 0,001518 | 0,01462 | 353,9 | 642,4 | 288,5 |
| 122,0 | 324,41 | 0,001526 | 0,01431 | 355,8 | 641,4 | 285,6 |
| 124,0 | 325,65 | 0,001534 | 0,01401 | 357,7 | 640,4 | 282,7 |
| 126,0 | 326,88 | 0,001542 | 0,01371 | 359,6 | 639,4 | 279,8 |
| 128,0 | 328,10 | 0,001550 | 0,01342 | 361,5 | 638,4 | 276,9 |
| 130,0 | 329,30 | 0,001558 | 0,01314 | 363,3 | 637,3 | 274,0 |
| 132,0 | 330,48 | 0,001566 | 0,01286 | 365,2 | 636,2 | 271,0 |
| 134,0 | 331,65 | 0,001574 | 0,01259 | 367,1 | 635,1 | 268,0 |
| 136,0 | 332,81 | 0,001582 | 0,01232 | 369,0 | 634,0 | 265,0 |
| 138,0 | 333,96 | 0,001591 | 0,01207 | 370,8 | 632,8 | 262,0 |
| 140,0 | 335,09 | 0,001600 | 0,01182 | 372,6 | 631,6 | 259,0 |
| 142,0 | 336,21 | 0,001608 | 0,01158 | 374,5 | 630,5 | 256,0 |
| 144,0 | 337,31 | 0,001616 | 0,01134 | 376,3 | 629,3 | 253,0 |
| 146,0 | 338,40 | 0,001625 | 0,01111 | 378,2 | 628,1 | 249,9 |
| 148,0 | 339,49 | 0,001635 | 0,01089 | 380,0 | 626,8 | 246,8 |
| 150,0 | 340,56 | 0,001644 | 0,01067 | 381,9 | 625,6 | 243,7 |
| 152,0 | 341,61 | 0,001653 | 0,01046 | 383,7 | 624,3 | 240,6 |
| 154,0 | 342,66 | 0,001663 | 0,01024 | 385,6 | 623,0 | 237,4 |
| 156,0 | 343,70 | 0,001673 | 0,01003 | 387,4 | 621,6 | 234,2 |
| 158,0 | 344,72 | 0,001683 | 0,009826 | 389,2 | 620,3 | 231,1 |
| 160,0 | 345,74 | 0,001693 | 0,009626 | 391,0 | 618,9 | 227,9 |
| 162,0 | 346,74 | 0,001704 | 0,009430 | 392,9 | 617,5 | 224,6 |
| 164,0 | 347,74 | 0,001715 | 0,009237 | 394,8 | 616,0 | 221,2 |
| 166,0 | 348,72 | 0,001726 | 0,009047 | 396,7 | 614,5 | 217,8 |
| 168,0 | 349,70 | 0,001738 | 0,008862 | 398,6 | 613,0 | 214,4 |
| 170,0 | 350,66 | 0,001750 | 0,008680 | 400,4 | 611,4 | 211,0 |
| 172,0 | 351,62 | 0,001762 | 0,008500 | 402,3 | 609,8 | 207,5 |
| 174,0 | 352,56 | 0,001773 | 0,008322 | 404,2 | 608,1 | 203,9 |
| 176,0 | 353,50 | 0,001785 | 0,008146 | 406,2 | 606,4 | 200,2 |
| 178,0 | 354,43 | 0,001798 | 0,007974 | 408,1 | 604,6 | 196,5 |
| 180,0 | 355,35 | 0,001812 | 0,007804 | 410,1 | 602,8 | 192,7 |
| 182,0 | 356,26 | 0,001827 | 0,007635 | 412,1 | 601,9 | 188,8 |
| 184,0 | 357,16 | 0,001842 | 0,007467 | 414,2 | 599,0 | 184,8 |
| 186,0 | 358,06 | 0,001857 | 0,007303 | 416,2 | 597,0 | 180,8 |
| 188,0 | 358,94 | 0,001873 | 0,007139 | 418,2 | 595,1 | 176,9 |
| 190,0 | 359,82 | 0,001889 | 0,00697 | 420,2 | 592,9 | 172,7 |
| 192,0 | 360,69 | 0,001909 | 0,00681 | 422,3 | 590,7 | 168,4 |
| 194,0 | 361,55 | 0,001929 | 0,00665 | 424,5 | 588,4 | 163,9 |
| 196,0 | 362,40 | 0,001950 | 0,00649 | 426,8 | 586,1 | 159,3 |
| 198,0 | 363,25 | 0,001970 | 0,00633 | 429,1 | 583,7 | 154,6 |
| 200,0 | 364,08 | 0,00199 | 0,00618 | 431,4 | 581,1 | 149,7 |
| 202,0 | 364,91 | 0,00201 | 0,00602 | 433,8 | 578,4 | 144,6 |
| 204,0 | 365,74 | 0,00203 | 0,00586 | 436,4 | 575,6 | 139,2 |
| 206,0 | 366,55 | 0,00206 | 0,00569 | 439,0 | 572,6 | 133,6 |
| 208,0 | 367,36 | 0,00209 | 0,00552 | 441,7 | 569,4 | 127,7 |
| 210,0 | 368,16 | 0,00213 | 0,00535 | 444,6 | 566,0 | 121,4 |
| 212,0 | 368,95 | 0,00217 | 0,00517 | 447,6 | 562,2 | 114,6 |
| 214,0 | 369,74 | 0,00221 | 0,00499 | 450,8 | 558,2 | 107,4 |
| 216,0 | 370,51 | 0,00225 | 0,00480 | 454,3 | 553,6 | 99,3 |
| 218,0 | 371,29 | 0,00231 | 0,00460 | 458,4 | 548,4 | 90,0 |
| 220,0 | 372,1 | 0,00239 | 0,00438 | 463,0 | 542,3 | 79,3 |
| 222,0 | 372,8 | 0,00248 | 0,00416 | 469,0 | 536,6 | 67,6 |
| 224,0 | 373,6 | 0,00265 | 0,00384 | 478,0 | 526,6 | 48,6 |

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B. Water.

| t, °C | v, m³/kg | i, kcal/kg | v, m³/kg | i, kcal/kg | v, m³/kg | i, kcal/kg |
|---|---|---|---|---|---|---|
| | p = 1,0 ama (1) | | p = 2,0 ama (1) | | p = 3,0 ama (1) | |
| 0 | 0,0010002 | 0,0 | 0,0010001 | 0,0 | 0,0010001 | 0,1 |
| 10 | 0,0010003 | 10,1 | 0,0010003 | 10,1 | 0,0010002 | 10,1 |
| 20 | 0,0010018 | 20,1 | 0,0010018 | 20,1 | 0,0010017 | 20,1 |
| 30 | 0,0010044 | 30,0 | 0,0010043 | 30,0 | 0,0010043 | 30,1 |
| 40 | 0,0010079 | 40,0 | 0,0010078 | 40,0 | 0,0010078 | 40,0 |
| 50 | 0,0010121 | 50,0 | 0,0010120 | 50,0 | 0,0010120 | 50,0 |
| 60 | 0,0010170 | 60,0 | 0,0010170 | 60,0 | 0,0010170 | 60,0 |
| 70 | 0,0010226 | 70,0 | 0,0010227 | 70,0 | 0,0010226 | 70,0 |
| 80 | 0,0010289 | 80,0 | 0,0010289 | 80,0 | 0,0010288 | 80,0 |
| 90 | 0,0010359 | 90,1 | 0,0010358 | 90,1 | 0,0010358 | 90,1 |
| 100 | | | 0,0010434 | 100,2 | 0,0010434 | 100,2 |
| 110 | | | 0,0010515 | 110,2 | 0,0010515 | 110,2 |
| 120 | | | | | 0,0010602 | 120,3 |
| 130 | | | | | 0,0010697 | 130,5 |
| | p = 4,0 ama (1) | | p = 6,0 ama (1) | | p = 8,0 ama (1) | |
| 0 | 0,0010000 | 0,1 | 0,0009999 | 0,1 | 0,0009998 | 0,2 |
| 10 | 0,0010002 | 10,1 | 0,0010001 | 10,2 | 0,0010000 | 10,2 |
| 20 | 0,0010017 | 20,1 | 0,0010016 | 20,2 | 0,0010015 | 20,2 |
| 30 | 0,0010042 | 30,1 | 0,0010041 | 30,1 | 0,0010040 | 30,2 |
| 40 | 0,0010077 | 40,1 | 0,0010077 | 40,1 | 0,0010076 | 40,2 |
| 50 | 0,0010119 | 50,0 | 0,0010118 | 50,1 | 0,0010118 | 50,1 |
| 60 | 0,0010169 | 60,0 | 0,0010168 | 60,1 | 0,0010167 | 60,1 |
| 70 | 0,0010226 | 70,0 | 0,0010225 | 70,1 | 0,0010224 | 70,1 |
| 80 | 0,0010288 | 80,0 | 0,0010287 | 80,1 | 0,0010286 | 80,1 |
| 90 | 0,0010357 | 90,1 | 0,0010356 | 90,2 | 0,0010355 | 90,2 |
| 100 | 0,0010433 | 100,2 | 0,0010432 | 100,2 | 0,0010431 | 100,3 |
| 110 | 0,0010514 | 110,3 | 0,0010513 | 110,3 | 0,0010512 | 110,3 |
| 120 | 0,0010602 | 120,4 | 0,0010601 | 120,4 | 0,0010600 | 120,4 |
| 130 | 0,0010697 | 130,6 | 0,0010696 | 130,6 | 0,0010695 | 130,6 |
| 140 | 0,0010798 | 140,8 | 0,0010797 | 140,8 | 0,0010795 | 140,8 |
| 150 | | | 0,0010906 | 151,0 | 0,0010904 | 151,1 |
| 160 | | | | | 0,0011020 | 161,4 |
| | p = 10,0 ama (1) | | p = 15,0 ama (1) | | p = 20,0 ama (1) | |
| 0 | 0,0009997 | 0,2 | 0,0009994 | 0,4 | 0,0009992 | 0,5 |
| 10 | 0,0009999 | 10,3 | 0,0009997 | 10,4 | 0,0009994 | 10,5 |
| 20 | 0,0010014 | 20,3 | 0,0010012 | 20,4 | 0,0010010 | 20,5 |
| 30 | 0,0010040 | 30,2 | 0,0010037 | 30,3 | 0,0010035 | 30,4 |
| 40 | 0,0010075 | 40,2 | 0,0010073 | 40,3 | 0,0010070 | 40,4 |
| 50 | 0,0010117 | 50,2 | 0,0010115 | 50,2 | 0,0010112 | 50,4 |
| 60 | 0,0010166 | 60,1 | 0,0010164 | 60,2 | 0,0010164 | 60,3 |
| 70 | 0,0010223 | 70,1 | 0,0010221 | 70,2 | 0,0010218 | 70,3 |
| 80 | 0,0010285 | 80,1 | 0,0010283 | 80,2 | 0,0010280 | 80,3 |
| 90 | 0,0010354 | 90,2 | 0,0010352 | 90,3 | 0,0010349 | 90,4 |
| 100 | 0,0010430 | 100,3 | 0,0010427 | 100,4 | 0,0010424 | 100,5 |
| 110 | 0,0010511 | 110,4 | 0,0010508 | 110,5 | 0,0010506 | 110,5 |
| 120 | 0,0010599 | 120,5 | 0,0010596 | 120,6 | 0,0010593 | 120,6 |
| 130 | 0,0010694 | 130,7 | 0,0010691 | 130,7 | 0,0010688 | 130,8 |
| 140 | 0,0010794 | 140,8 | 0,0010791 | 140,9 | 0,0010788 | 141,0 |
| 150 | 0,0010902 | 151,1 | 0,0010899 | 151,2 | 0,0010896 | 151,2 |
| 160 | 0,0011018 | 161,4 | 0,0011015 | 161,5 | 0,0011011 | 161,5 |
| 170 | 0,0011142 | 171,8 | 0,0011139 | 171,9 | 0,0011135 | 171,9 |
| 180 | | | 0,0011271 | 182,3 | 0,0011267 | 182,4 |
| 190 | | | 0,0011413 | 192,9 | 0,0011409 | 193,0 |
| 200 | | | | | 0,0011561 | 203,6 |
| 210 | | | | | 0,0011726 | 214,4 |
| | p = 30 ama (1) | | p = 40 ama (1) | | p = 50 ama (1) | |
| 0 | 0,0009987 | 0,7 | 0,0009982 | 1,0 | 0,0009977 | 1,2 |
| 10 | 0,0009990 | 10,7 | 0,0009985 | 10,9 | 0,0009981 | 11,2 |
| 20 | 0,0010005 | 20,7 | 0,0010001 | 20,9 | 0,0009997 | 21,1 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| 30 | 0,0010031 | 30,6 | 0,0010027 | 30,9 | 0,0010022 | 31,1 |
| 40 | 0,0010066 | 40,6 | 0,0010062 | 40,8 | 0,0010057 | 41,0 |
| 50 | 0,0010108 | 50,6 | 0,0010103 | 50,8 | 0,0010099 | 51,0 |
| 60 | 0,0010157 | 60,5 | 0,0010152 | 60,7 | 0,0010148 | 60,9 |
| 70 | 0,0010213 | 70,5 | 0,0010208 | 70,7 | 0,0010204 | 70,9 |
| 80 | 0,0010275 | 80,5 | 0,0010271 | 80,7 | 0,0010266 | 80,9 |
| 90 | 0,0010344 | 90,6 | 0,0010339 | 90,8 | 0,0010334 | 91,0 |
| 100 | 0,0010419 | 100,6 | 0,0010414 | 100,8 | 0,0010409 | 101,0 |
| 110 | 0,0010501 | 110,7 | 0,0010495 | 110,9 | 0,0010490 | 111,1 |
| 120 | 0,0010588 | 120,8 | 0,0010582 | 121,0 | 0,0010577 | 121,2 |
| 130 | 0,0010682 | 131,0 | 0,0010676 | 131,1 | 0,0010670 | 131,3 |
| 140 | 0,0010782 | 141,2 | 0,0010776 | 141,3 | 0,0010770 | 141,5 |
| 150 | 0,0010890 | 151,4 | 0,0010883 | 151,5 | 0,0010877 | 151,7 |
| 160 | 0,0011004 | 161,7 | 0,0010997 | 161,8 | 0,0010990 | 161,9 |
| 170 | 0,0011127 | 172,0 | 0,0011120 | 172,2 | 0,0011113 | 172,3 |
| 180 | 0,0011259 | 182,5 | 0,0011251 | 182,6 | 0,0011243 | 182,7 |
| 190 | 0,0011400 | 193,1 | 0,0011391 | 193,2 | 0,0011382 | 193,3 |
| 200 | 0,0011552 | 203,7 | 0,0011542 | 203,8 | 0,0011532 | 203,9 |
| 210 | 0,0011715 | 214,5 | 0,0011704 | 214,6 | 0,0011694 | 214,7 |
| 220 | 0,0011892 | 225,4 | 0,0011880 | 225,5 | 0,0011868 | 225,6 |
| 230 | 0,0012085 | 236,5 | 0,0012071 | 236,5 | 0,0012057 | 236,6 |
| 240 | | | 0,0012281 | 247,8 | 0,0012265 | 247,8 |
| 250 | | | | | 0,0012494 | 259,3 |
| 260 | | | | | 0,0012750 | 271,1 |
| | $p = 60$ ama (1) | | $p = 70$ ama (1) | | $p = 80$ ama (1) | |
| 0 | 0,0009972 | 1,4 | 0,0009967 | 1,7 | 0,0009962 | 1,9 |
| 10 | 0,0009976 | 11,4 | 0,0009972 | 11,6 | 0,0009967 | 11,9 |
| 20 | 0,0009992 | 21,3 | 0,0009988 | 21,6 | 0,0009983 | 21,8 |
| 30 | 0,0010018 | 31,3 | 0,0010014 | 31,5 | 0,0010009 | 31,7 |
| 40 | 0,0010053 | 41,2 | 0,0010049 | 41,4 | 0,0010045 | 41,6 |
| 50 | 0,0010095 | 51,2 | 0,0010090 | 51,4 | 0,0010086 | 51,6 |
| 60 | 0,0010144 | 61,1 | 0,0010139 | 61,3 | 0,0010135 | 61,5 |
| 70 | 0,0010199 | 71,1 | 0,0010195 | 71,3 | 0,0010190 | 71,5 |
| 80 | 0,0010262 | 81,1 | 0,0010257 | 81,3 | 0,0010252 | 81,5 |
| 90 | 0,0010329 | 91,2 | 0,0010325 | 91,3 | 0,0010320 | 91,5 |
| 100 | 0,0010404 | 101,2 | 0,0010399 | 101,3 | 0,0010394 | 101,5 |
| 110 | 0,0010485 | 111,2 | 0,0010480 | 111,4 | 0,0010475 | 111,6 |
| 120 | 0,0010572 | 121,3 | 0,0010566 | 121,5 | 0,0010561 | 121,7 |
| 130 | 0,0010665 | 131,4 | 0,0010659 | 131,6 | 0,0010653 | 131,8 |
| 140 | 0,0010764 | 141,6 | 0,0010758 | 141,8 | 0,0010752 | 141,9 |
| 150 | 0,0010870 | 151,8 | 0,0010864 | 152,0 | 0,0010858 | 152,1 |
| 160 | 0,0010984 | 162,1 | 0,0010977 | 162,2 | 0,0010970 | 162,4 |
| 170 | 0,0011105 | 172,4 | 0,0011098 | 172,5 | 0,0011091 | 172,7 |
| 180 | 0,0011235 | 182,9 | 0,0011226 | 183,0 | 0,0011219 | 183,1 |
| 190 | 0,0011374 | 193,4 | 0,0011365 | 193,5 | 0,0011356 | 193,6 |
| 200 | 0,0011522 | 204,0 | 0,0011513 | 204,1 | 0,0011504 | 204,2 |
| 210 | 0,0011683 | 214,7 | 0,0011673 | 214,8 | 0,0011662 | 214,9 |
| 220 | 0,0011857 | 225,6 | 0,0011845 | 225,7 | 0,0011883 | 225,8 |
| 230 | 0,0012044 | 236,6 | 0,0012031 | 236,7 | 0,0012018 | 236,7 |
| 240 | 0,0012250 | 247,8 | 0,0012235 | 247,9 | 0,0012220 | 247,9 |
| 250 | 0,0012477 | 259,3 | 0,0012459 | 259,3 | 0,0012442 | 259,3 |
| 260 | 0,0012728 | 271,0 | 0,0012708 | 271,0 | 0,0012688 | 271,0 |
| 270 | 0,0013013 | 283,1 | 0,0012988 | 283,0 | 0,0012964 | 283,0 |
| 280 | | | 0,0013307 | 295,3 | 0,0013278 | 295,2 |
| 290 | | | | | 0,0013639 | 308,0 |
| | $p = 90$ ama (1) | | $p = 100$ ama (1) | | $p = 110$ ama (1) | |
| 0 | 0,0009957 | 2,2 | 0,0009952 | 2,4 | 0,0009948 | 2,6 |
| 10 | 0,0009962 | 12,1 | 0,0009958 | 12,3 | 0,0009953 | 12,5 |
| 20 | 0,0009979 | 22,0 | 0,0009975 | 22,2 | 0,0009971 | 22,4 |
| 30 | 0,0010005 | 31,9 | 0,0010001 | 32,1 | 0,0009997 | 32,3 |
| 40 | 0,0010040 | 41,8 | 0,0010036 | 42,1 | 0,0010032 | 42,3 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| 50 | 0,0010082 | 51,8 | 0,0010077 | 52,0 | 0,0010074 | 52,2 |
| 60 | 0,0010130 | 61,7 | 0,0010126 | 61,9 | 0,0010122 | 62,1 |
| 70 | 0,0010186 | 71,7 | 0,0010181 | 71,8 | 0,0010177 | 72,0 |
| 80 | 0,0010248 | 81,6 | 0,0010243 | 81,8 | 0,0010239 | 82,0 |
| 90 | 0,0010315 | 91,7 | 0,0010311 | 91,9 | 0,0010306 | 92,1 |
| 100 | 0,0010389 | 101,7 | 0,0010384 | 101,9 | 0,0010380 | 102,1 |
| 110 | 0,0010470 | 111,8 | 0,0010464 | 111,9 | 0,0010459 | 112,1 |
| 120 | 0,0010556 | 121,8 | 0,0010550 | 122,0 | 0,0010545 | 122,2 |
| 130 | 0,0010648 | 131,9 | 0,0010642 | 132,1 | 0,0010637 | 132,3 |
| 140 | 0,0010746 | 142,1 | 0,0010740 | 142,2 | 0,0010735 | 142,4 |
| 150 | 0,0010851 | 152,3 | 0,0010845 | 152,4 | 0,0010839 | 152,6 |
| 160 | 0,0010963 | 162,5 | 0,0010957 | 162,6 | 0,0010950 | 162,8 |
| 170 | 0,0011083 | 172,8 | 0,0011076 | 172,9 | 0,0011069 | 173,1 |
| 180 | 0,0011211 | 183,2 | 0,0011203 | 183,3 | 0,0011195 | 183,4 |
| 190 | 0,0011348 | 193,7 | 0,0011339 | 193,8 | 0,0011331 | 193,9 |
| 200 | 0,0011494 | 204,3 | 0,0011485 | 204,4 | 0,0011476 | 204,5 |
| 210 | 0,0011652 | 215,0 | 0,0011642 | 215,1 | 0,0011631 | 215,2 |
| 220 | 0,0011822 | 225,8 | 0,0011810 | 225,9 | 0,0011799 | 226,0 |
| 230 | 0,0012005 | 236,8 | 0,0011992 | 236,8 | 0,0011979 | 236,9 |
| 240 | 0,0012205 | 248,0 | 0,0012191 | 248,0 | 0,0012176 | 248,0 |
| 250 | 0,0012424 | 259,4 | 0,0012408 | 259,4 | 0,0012392 | 259,4 |
| 260 | 0,0012668 | 271,0 | 0,0012649 | 271,0 | 0,0012630 | 271,0 |
| 270 | 0,0012941 | 282,8 | 0,0012918 | 282,8 | 0,0012895 | 282,7 |
| 280 | 0,0013249 | 295,1 | 0,0013221 | 295,0 | 0,0013193 | 294,8 |
| 290 | 0,0013603 | 307,8 | 0,0013568 | 307,6 | 0,0013536 | 307,4 |
| 300 | 0,0014023 | 321,1 | 0,0013978 | 320,9 | 0,0013936 | 320,5 |
| 310 | | | | | 0,001442 | 334,5 |
| | $p = 120$ ama | | $p = 130$ ama | | $p = 140$ ama | |
| 0 | 0,0009943 | 2,9 | 0,0009938 | 3,1 | 0,0009933 | 3,3 |
| 10 | 0,0009949 | 12,8 | 0,0009944 | 13,0 | 0,0009940 | 13,2 |
| 20 | 0,0009966 | 22,7 | 0,0009962 | 22,9 | 0,0009958 | 23,1 |
| 30 | 0,0009993 | 32,6 | 0,0009989 | 32,8 | 0,0009985 | 33,0 |
| 40 | 0,0010028 | 42,5 | 0,0010023 | 42,7 | 0,0010019 | 42,9 |
| 50 | 0,0010069 | 52,4 | 0,0010065 | 52,6 | 0,0010061 | 52,8 |
| 60 | 0,0010117 | 62,3 | 0,0010113 | 62,5 | 0,0010109 | 62,7 |
| 70 | 0,0010172 | 72,2 | 0,0010168 | 72,4 | 0,0010164 | 72,6 |
| 80 | 0,0010234 | 82,2 | 0,0010229 | 82,4 | 0,0010225 | 82,6 |
| 90 | 0,0010301 | 92,2 | 0,0010297 | 92,4 | 0,0010292 | 92,6 |
| 100 | 0,0010375 | 102,2 | 0,0010370 | 102,4 | 0,0010365 | 102,6 |
| 110 | 0,0010454 | 112,3 | 0,0010450 | 112,4 | 0,0010444 | 112,6 |
| 120 | 0,0010540 | 122,3 | 0,0010535 | 122,5 | 0,0010529 | 122,7 |
| 130 | 0,0010631 | 132,4 | 0,0010626 | 132,6 | 0,0010620 | 132,8 |
| 140 | 0,0010728 | 142,5 | 0,0010723 | 142,7 | 0,0010717 | 142,9 |
| 150 | 0,0010832 | 152,7 | 0,0010826 | 152,8 | 0,0010820 | 153,0 |
| 160 | 0,0010943 | 162,9 | 0,0010937 | 163,0 | 0,0010930 | 163,2 |
| 170 | 0,0011062 | 173,2 | 0,0011055 | 173,3 | 0,0011047 | 173,5 |
| 180 | 0,0011188 | 183,6 | 0,0011180 | 183,7 | 0,0011172 | 183,8 |
| 190 | 0,0011322 | 194,0 | 0,0011314 | 194,1 | 0,0011306 | 194,2 |
| 200 | 0,0011466 | 204,6 | 0,0011457 | 204,7 | 0,0011448 | 204,8 |
| 210 | 0,0011621 | 215,2 | 0,0011611 | 215,3 | 0,0011601 | 215,4 |
| 220 | 0,0011788 | 226,0 | 0,0011777 | 226,1 | 0,0011766 | 226,2 |
| 230 | 0,0011967 | 236,9 | 0,0011954 | 237,0 | 0,0011942 | 237,1 |
| 240 | 0,0012162 | 248,1 | 0,0012148 | 248,1 | 0,0012135 | 248,1 |
| 250 | 0,0012376 | 259,4 | 0,0012360 | 259,4 | 0,0012345 | 259,4 |
| 260 | 0,0012612 | 270,9 | 0,0012593 | 270,9 | 0,0012575 | 270,9 |
| 270 | 0,0012874 | 282,7 | 0,0012852 | 282,6 | 0,0012831 | 282,6 |
| 280 | 0,0013168 | 294,7 | 0,0013142 | 294,6 | 0,0013117 | 294,6 |
| 290 | 0,0013504 | 307,2 | 0,0013473 | 307,0 | 0,0013442 | 307,0 |
| 300 | 0,0013896 | 320,2 | 0,0013857 | 320,0 | 0,0013819 | 319,7 |
| 310 | 0,001436 | 334,1 | 0,001431 | 333,7 | 0,001426 | 333,3 |
| 320 | 0,001495 | 348,9 | 0,001487 | 348,3 | 0,001481 | 347,[illegible] |
| 330 | | | | | 0,001552 | 363,6 |

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| | $p$ = 150 ama | | $p$ = 160 ama | | $p$ = 170 ama | |
|---|---|---|---|---|---|---|
| 0 | 0,0009929 | 3,6 | 0,0009924 | 3,9 | 0,0009919 | 4,0 |
| 10 | 0,0009936 | 13,4 | 0,0009932 | 13,6 | 0,0009927 | 13,9 |
| 20 | 0,0009954 | 23,3 | 0,0009950 | 23,5 | 0,0009945 | 23,7 |
| 30 | 0,0009981 | 33,2 | 0,0009976 | 33,4 | 0,0009972 | 33,6 |
| 40 | 0,0010015 | 43,1 | 0,0010011 | 43,3 | 0,0010007 | 43,5 |
| 50 | 0,0010056 | 53,0 | 0,0010052 | 53,2 | 0,0010048 | 53,4 |
| 60 | 0,0010104 | 62,9 | 0,0010100 | 63,1 | 0,0010096 | 63,3 |
| 70 | 0,0010159 | 72,8 | 0,0010155 | 73,0 | 0,0010150 | 73,2 |
| 80 | 0,0010221 | 82,8 | 0,0010216 | 83,0 | 0,0010211 | 83,2 |
| 90 | 0,0010288 | 92,8 | 0,0010283 | 93,0 | 0,0010278 | 93,2 |
| 100 | 0,0010360 | 102,8 | 0,0010356 | 103,0 | 0,0010351 | 103,1 |
| 110 | 0,0010439 | 112,8 | 0,0010434 | 113,0 | 0,0010429 | 113,1 |
| 120 | 0,0010524 | 122,8 | 0,0010519 | 123,0 | 0,0010514 | 123,2 |
| 130 | 0,0010615 | 132,9 | 0,0010609 | 133,1 | 0,0010604 | 133,2 |
| 140 | 0,0010711 | 143,0 | 0,0010705 | 143,2 | 0,0010700 | 143,3 |
| 150 | 0,0010814 | 153,1 | 0,0010808 | 153,3 | 0,0010802 | 153,5 |
| 160 | 0,0010924 | 163,3 | 0,0010917 | 163,5 | 0,0010911 | 163,6 |
| 170 | 0,0011041 | 173,6 | 0,0011033 | 173,7 | 0,0011027 | 173,8 |
| 180 | 0,0011165 | 183,9 | 0,0011157 | 184,0 | 0,0011150 | 184,1 |
| 190 | 0,0011297 | 194,3 | 0,0011289 | 194,4 | 0,0011281 | 194,6 |
| 200 | 0,0011439 | 204,9 | 0,0011430 | 205,0 | 0,0011422 | 205,1 |
| 210 | 0,0011591 | 215,5 | 0,0011582 | 215,6 | 0,0011572 | 215,7 |
| 220 | 0,0011755 | 226,2 | 0,0011744 | 226,3 | 0,0011733 | 226,4 |
| 230 | 0,0011930 | 237,1 | 0,0011918 | 237,1 | 0,0011906 | 237,2 |
| 240 | 0,0012121 | 248,1 | 0,0012107 | 248,2 | 0,0012094 | 248,2 |
| 250 | 0,0012329 | 259,4 | 0,0012313 | 259,4 | 0,0012298 | 259,4 |
| 260 | 0,0012557 | 270,9 | 0,0012540 | 270,8 | 0,0012522 | 270,8 |
| 270 | 0,0012810 | 282,6 | 0,0012790 | 282,5 | 0,0012770 | 282,5 |
| 280 | 0,0013093 | 294,5 | 0,0013069 | 294,5 | 0,0013045 | 294,4 |
| 290 | 0,0013413 | 306,8 | 0,0013384 | 306,7 | 0,0013355 | 306,6 |
| 300 | 0,0013781 | 319,5 | 0,0013745 | 319,3 | 0,0013711 | 319,1 |
| 310 | 0,001421 | 332,9 | 0,001417 | 332,5 | 0,001412 | 332,2 |
| 320 | 0,001474 | 347,1 | 0,001468 | 346,6 | 0,001462 | 346,2 |
| 330 | 0,001542 | 362,8 | 0,001533 | 362,0 | 0,001525 | 361,3 |
| 340 | 0,001637 | 380,8 | 0,001619 | 379,4 | 0,001606 | 378,2 |
| 350 | | | | | 0,001736 | 398,8 |

| | $p$ = 180 ama | | $p$ = 190 ama | | $p$ = 200 ama | |
|---|---|---|---|---|---|---|
| 0 | 0,0009914 | 4,3 | 0,0009910 | 4,5 | 0,0009905 | 4,7 |
| 10 | 0,0009922 | 14,1 | 0,0009918 | 14,3 | 0,0009914 | 14,6 |
| 20 | 0,0009941 | 24,0 | 0,0009937 | 24,2 | 0,0009933 | 24,4 |
| 30 | 0,0009968 | 33,8 | 0,0009964 | 34,0 | 0,0009960 | 34,3 |
| 40 | 0,0010003 | 43,7 | 0,0009999 | 43,9 | 0,0009995 | 44,1 |
| 50 | 0,0010044 | 53,6 | 0,0010040 | 53,8 | 0,0010036 | 54,0 |
| 60 | 0,0010092 | 63,5 | 0,0010087 | 63,7 | 0,0010083 | 63,8 |
| 70 | 0,0010146 | 73,4 | 0,0010142 | 73,6 | 0,0010137 | 73,7 |
| 80 | 0,0010207 | 82,3 | 0,0010203 | 83,5 | 0,0010198 | 83,7 |
| 90 | 0,0010274 | 93,3 | 0,0010269 | 93,5 | 0,0010265 | 93,7 |
| 100 | 0,0010347 | 103,3 | 0,0010342 | 103,5 | 0,0010337 | 103,7 |
| 110 | 0,0010425 | 113,3 | 0,0010420 | 113,5 | 0,0010415 | 113,7 |
| 120 | 0,0010508 | 123,3 | 0,0010503 | 123,5 | 0,0010498 | 123,7 |
| 130 | 0,0010598 | 133,4 | 0,0010593 | 133,5 | 0,0010588 | 133,8 |
| 140 | 0,0010694 | 143,5 | 0,0010688 | 143,6 | 0,0010682 | 143,8 |
| 150 | 0,0010796 | 153,6 | 0,0010790 | 153,8 | 0,0010784 | 153,9 |
| 160 | 0,0010905 | 163,8 | 0,0010898 | 163,9 | 0,0010892 | 164,0 |
| 170 | 0,0011020 | 174,0 | 0,0011013 | 174,1 | 0,0011006 | 174,2 |
| 180 | 0,0011143 | 184,3 | 0,0011135 | 184,4 | 0,0011128 | 184,5 |
| 190 | 0,0011273 | 194,7 | 0,0011265 | 194,8 | 0,0011257 | 194,9 |

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cont.

| | | | | | | |
|---|---|---|---|---|---|---|
| 200 | 0,0011412 | 205,2 | 0,0011404 | 205,3 | 0,0011395 | 205,4 |
| 210 | 0,0011562 | 215,7 | 0,0011553 | 215,8 | 0,0011543 | 215,9 |
| 220 | 0,0011722 | 226,4 | 0,0011712 | 226,5 | 0,0011701 | 226,6 |
| 230 | 0,0011894 | 237,3 | 0,0011882 | 237,3 | 0,0011870 | 237,4 |
| 240 | 0,0012081 | 248,3 | 0,0012067 | 248,3 | 0,0012054 | 248,3 |
| 250 | 0,0012283 | 259,5 | 0,0012268 | 259,5 | 0,0012253 | 259,5 |
| 260 | 0,0012505 | 270,8 | 0,0012488 | 270,8 | 0,0012471 | 270,8 |
| 270 | 0,0012750 | 282,4 | 0,0012730 | 282,4 | 0,0012711 | 282,3 |
| 280 | 0,0013022 | 294,3 | 0,0012999 | 294,3 | 0,0012976 | 294,1 |
| 290 | 0,0013328 | 306,5 | 0,0013308 | 306,4 | 0,0013273 | 306,2 |
| 300 | 0,0013677 | 319,0 | 0,0013644 | 318,8 | 0,0013611 | 318,6 |
| 310 | 0,001408 | 331,9 | 0,001404 | 331,6 | 0,001400 | 331,4 |
| 320 | 0,001457 | 345,7 | 0,001452 | 345,3 | 0,001446 | 344,9 |
| 330 | 0,001517 | 360,7 | 0,001509 | 360,0 | 0,001501 | 359,5 |
| 340 | 0,001594 | 377,1 | 0,001582 | 376,1 | 0,001571 | 375,2 |
| 350 | 0,001707 | 396,7 | 0,001684 | 394,9 | 0,001665 | 393,4 |
| 360 | | | | | 0,001828 | 416,4 |
| | $p = 210$ ama (1) | | $p = 220$ ama (1) | | | |
| 0 | 0,0009900 | 5,0 | 0,0009896 | 5,2 | | |
| 10 | 0,0009909 | 14,8 | 0,0009905 | 15,0 | | |
| 20 | 0,0009928 | 24,6 | 0,0009924 | 24,9 | | |
| 30 | 0,0009956 | 34,5 | 0,0009952 | 34,7 | | |
| 40 | 0,0009990 | 44,3 | 0,0009986 | 44,5 | | |
| 50 | 0,0010031 | 54,2 | 0,0010027 | 54,4 | | |
| 60 | 0,0010079 | 64,0 | 0,0010075 | 64,2 | | |
| 70 | 0,0010133 | 73,9 | 0,0010129 | 74,1 | | |
| 80 | 0,0010194 | 83,9 | 0,0010190 | 84,0 | | |
| 90 | 0,0010260 | 93,9 | 0,0010256 | 94,1 | | |
| 100 | 0,0010332 | 103,8 | 0,0010328 | 104,0 | | |
| 110 | 0,0010410 | 113,8 | 0,0010405 | 114,0 | | |
| 120 | 0,0010493 | 123,8 | 0,0010488 | 124,0 | | |
| 130 | 0,0010582 | 133,9 | 0,0010577 | 134,0 | | |
| 140 | 0,0010677 | 144,0 | 0,0010671 | 144,1 | | |
| 150 | 0,0010778 | 154,1 | 0,0010772 | 154,2 | | |
| 160 | 0,0010886 | 164,2 | 0,0010879 | 164,3 | | |
| 170 | 0,0011000 | 174,4 | 0,0010992 | 174,5 | | |
| 180 | 0,0011121 | 184,6 | 0,0011113 | 184,8 | | |
| 190 | 0,0011250 | 195,0 | 0,0011242 | 195,1 | | |
| 200 | 0,0011387 | 205,5 | 0,0011379 | 205,5 | | |
| 210 | 0,0011534 | 216,0 | 0,0011524 | 216,1 | | |
| 220 | 0,0011691 | 226,6 | 0,0011680 | 226,7 | | |
| 230 | 0,0011859 | 237,4 | 0,0011847 | 237,5 | | |
| 240 | 0,0012041 | 248,3 | 0,0012028 | 248,4 | | |
| 250 | 0,0012239 | 259,5 | 0,0012221 | 259,5 | | |
| 260 | 0,0012455 | 270,8 | 0,0012438 | 270,8 | | |
| 270 | 0,0012692 | 282,3 | 0,0012673 | 282,3 | | |
| 280 | 0,0012954 | 294,1 | 0,0012932 | 294,0 | | |
| 290 | 0,0013247 | 306,1 | 0,0013221 | 305,9 | | |
| 300 | 0,0013579 | 318,3 | 0,0013548 | 318,2 | | |
| 310 | 0,001395 | 331,2 | 0,001392 | 331,0 | | |
| 320 | 0,001441 | 344,5 | 0,001436 | 344,4 | | |
| 330 | 0,001494 | 359,0 | 0,001488 | 358,6 | | |
| 340 | 0,001562 | 374,5 | 0,001552 | 373,7 | | |
| 350 | 0,001649 | 392,1 | 0,001636 | 390,9 | | |
| 360 | 0,001785 | 413,2 | 0,001755 | 410,8 | | |
| 370 | | | 0,002085 | 443,4 | | |

AD-A085 487 FOREIGN TECHNOLOGY DIV WRIGHT-PATTERSON AFB OH F/G 13/1
THERMAL DESIGN OF BOILER UNIT (STANDARD METHOD).(U)
APR 80
UNCLASSIFIED FTD-ID(RS)T-0411-80 NL


AD
A085487

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C. Superheated steam.

| t, °C | m³/kg | kcal/kg | m³/kg | kcal/kg | m³/kg | kcal/kg |
|---|---|---|---|---|---|---|
| | $p = 1{,}0$ ama (1) | | $p = 1{,}5$ ama (1) | | $p = 2{,}0$ ama (1) | |
| 100 | 1,729 | 639,0 | | | | |
| 110 | 1,779 | 643,8 | | | | |
| 120 | 1,829 | 648,6 | 1,211 | 647,6 | 0,9030 | 646,4 |
| 130 | 1,878 | 653,4 | 1,245 | 652,4 | 0,9287 | 651,4 |
| 140 | 1,926 | 658,1 | 1,278 | 657,3 | 0,9540 | 656,3 |
| 150 | 1,975 | 662,9 | 1,311 | 662,1 | 0,9791 | 661,2 |
| 160 | 2,023 | 667,7 | 1,344 | 666,9 | 1,004 | 666,1 |
| 170 | 2,071 | 672,5 | 1,376 | 671,7 | 1,029 | 671,0 |
| 180 | 2,119 | 677,2 | 1,409 | 676,5 | 1,053 | 675,9 |
| 190 | 2,167 | 681,9 | 1,441 | 681,3 | 1,078 | 680,7 |
| 200 | 2,215 | 686,6 | 1,473 | 686,1 | 1,102 | 685,5 |
| 210 | 2,263 | 691,3 | 1,505 | 690,8 | 1,126 | 690,3 |
| 220 | 2,311 | 696,0 | 1,537 | 695,6 | 1,150 | 695,1 |
| 230 | 2,358 | 700,8 | 1,569 | 700,4 | 1,174 | 699,9 |
| 240 | 2,406 | 705,5 | 1,601 | 705,1 | 1,198 | 704,7 |
| 250 | 2,454 | 710,3 | 1,633 | 709,9 | 1,222 | 709,5 |
| 260 | 2,501 | 715,0 | 1,664 | 714,7 | 1,246 | 714,3 |
| 270 | 2,548 | 719,8 | 1,696 | 719,5 | 1,270 | 719,1 |
| 280 | 2,596 | 724,6 | 1,728 | 724,3 | 1,294 | 723,9 |
| 290 | 2,643 | 729,4 | 1,760 | 729,1 | 1,318 | 728,8 |
| 300 | 2,690 | 734,2 | 1,791 | 733,9 | 1,342 | 733,7 |
| 310 | 2,738 | 739,0 | 1,823 | 738,7 | 1,366 | 738,5 |
| 320 | 2,785 | 743,8 | 1,855 | 743,6 | 1,390 | 743,3 |
| 330 | 2,832 | 748,7 | 1,886 | 748,4 | 1,413 | 748,2 |
| 340 | 2,880 | 753,5 | 1,918 | 753,3 | 1,437 | 753,0 |
| 350 | 2,927 | 758,4 | 1,949 | 758,1 | 1,461 | 757,9 |
| 360 | 2,974 | 763,3 | 1,981 | 763,0 | 1,485 | 762,8 |
| 370 | 3,022 | 768,2 | 2,013 | 768,0 | 1,508 | 767,8 |
| 380 | 3,069 | 773,1 | 2,044 | 772,9 | 1,532 | 772,7 |
| 390 | 3,116 | 778,0 | 2,076 | 777,8 | 1,556 | 777,6 |
| 400 | 3,163 | 782,9 | 2,107 | 782,7 | 1,579 | 782,5 |
| 410 | 3,211 | 787,9 | 2,139 | 787,7 | 1,603 | 787,5 |
| 420 | 3,258 | 792,9 | 2,170 | 792,7 | 1,627 | 792,5 |
| 430 | 3,305 | 797,8 | 2,202 | 797,7 | 1,651 | 797,5 |
| 440 | 3,352 | 802,8 | 2,233 | 802,7 | 1,674 | 802,5 |
| 450 | 3,399 | 807,8 | 2,265 | 807,7 | 1,698 | 807,5 |
| | $p = 2{,}5$ ama (1) | | $p = 3{,}0$ ama (1) | | $p = 4{,}0$ ama (1) | |
| 130 | 0,7387 | 650,3 | | | | |
| 140 | 0,7594 | 655,3 | 0,6296 | 654,4 | | |
| 150 | 0,7798 | 660,3 | 0,6469 | 659,5 | 0,4806 | 657,6 |
| 160 | 0,7999 | 665,3 | 0,6640 | 664,5 | 0,4938 | 662,8 |
| 170 | 0,8199 | 670,3 | 0,6809 | 669,5 | 0,5068 | 668,0 |
| 180 | 0,8398 | 675,2 | 0,6976 | 674,5 | 0,5197 | 673,1 |
| 190 | 0,8596 | 680,1 | 0,7142 | 679,5 | 0,5325 | 678,2 |
| 200 | 0,8792 | 685,0 | 0,7307 | 684,4 | 0,5451 | 683,2 |
| 210 | 0,8988 | 689,8 | 0,7471 | 689,3 | 0,5576 | 688,2 |
| 220 | 0,9183 | 694,6 | 0,7635 | 694,2 | 0,5700 | 693,2 |
| 230 | 0,9377 | 699,5 | 0,7798 | 699,0 | 0,5824 | 693,1 |
| 240 | 0,9570 | 704,3 | 0,7960 | 703,9 | 0,5947 | 703,1 |
| 250 | 0,9763 | 709,1 | 0,8122 | 708,8 | 0,6070 | 708,0 |
| 206 | 0,9955 | 713,9 | 0,8283 | 713,6 | 0,6192 | 712,9 |
| 270 | 1,015 | 718,8 | 0,8444 | 718,5 | 0,6314 | 717,8 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| 280 | 1,034 | 723,6 | 0,8605 | 723,3 | 0,6435 | 722,7 |
| 290 | 1,053 | 728,5 | 0,8766 | 728,1 | 0,6557 | 727,6 |
| 300 | 1,072 | 733,4 | 0,8926 | 733,0 | 0,6678 | 732,5 |
| 310 | 1,092 | 738,2 | 0,9085 | 737,9 | 0,6799 | 737,4 |
| 320 | 1,111 | 743,1 | 0,9245 | 742,8 | 0,6919 | 742,3 |
| 330 | 1,130 | 747,9 | 0,9405 | 747,7 | 0,7040 | 747,2 |
| 340 | 1,149 | 752,8 | 0,9564 | 752,6 | 0,7160 | 752,1 |
| 350 | 1,168 | 757,7 | 0,9723 | 757,5 | 0,7280 | 757,0 |
| 360 | 1,187 | 762,6 | 0,9883 | 762,4 | 0,7400 | 762,0 |
| 370 | 1,206 | 767,5 | 1,004 | 767,3 | 0,7519 | 766,9 |
| 380 | 1,225 | 772,5 | 1,020 | 772,3 | 0,7639 | 771,9 |
| 390 | 1,244 | 777,4 | 1,036 | 777,2 | 0,7758 | 776,8 |
| 400 | 1,263 | 782,4 | 1,052 | 782,2 | 0,7878 | 781,8 |
| 410 | 1,282 | 787,3 | 1,068 | 787,2 | 0,7997 | 786,8 |
| 420 | 1,301 | 792,3 | 1,083 | 792,2 | 0,8116 | 791,8 |
| 430 | 1,320 | 797,4 | 1,099 | 797,2 | 0,8235 | 796,9 |
| 440 | 1,339 | 802,4 | 1,115 | 802,2 | 0,8354 | 801,9 |
| 450 | 1,358 | 807,4 | 1,131 | 807,2 | 0,8473 | 807,0 |
| | $p = 5,0$ ama (1) | | $p = 6,0$ ama (1) | | $p = 7,0$ ama (1) | |
| 160 | 0,3917 | 661,0 | 0,3233 | 659,3 | | |
| 170 | 0,4021 | 666,4 | 0,3326 | 664,8 | 0,2827 | 663,1 |
| 180 | 0,4130 | 671,7 | 0,3417 | 670,2 | 0,2908 | 668,7 |
| 190 | 0,4231 | 676,9 | 0,3506 | 675,6 | 0,2986 | 674,2 |
| 200 | 0,4336 | 682,1 | 0,3593 | 680,9 | 0,3062 | 679,6 |
| 210 | 0,4438 | 687,2 | 0,3680 | 686,1 | 0,3138 | 684,9 |
| 220 | 0,4539 | 692,2 | 0,3766 | 691,2 | 0,3212 | 690,1 |
| 230 | 0,4640 | 697,2 | 0,3851 | 696,3 | 0,3285 | 695,3 |
| 240 | 0,4740 | 702,2 | 0,3935 | 701,3 | 0,3358 | 700,5 |
| 250 | 0,4839 | 707,2 | 0,4018 | 706,4 | 0,3431 | 705,6 |
| 260 | 0,4938 | 712,1 | 0,4101 | 711,4 | 0,3503 | 710,6 |
| 270 | 0,5036 | 717,1 | 0,4184 | 716,4 | 0,3575 | 715,7 |
| 280 | 0,5134 | 722,0 | 0,4266 | 721,4 | 0,3646 | 720,7 |
| 290 | 0,5232 | 726,9 | 0,4348 | 726,3 | 0,3717 | 725,7 |
| 300 | 0,5329 | 731,9 | 0,4430 | 731,3 | 0,3788 | 730,7 |
| 310 | [illegible] | 736,9 | 0,4512 | 736,2 | 0,3858 | 735,7 |
| 320 | 0,5524 | 741,7 | 0,4593 | 741,2 | 0,3928 | 740,7 |
| 330 | 0,5621 | 746,7 | 0,4674 | 746,2 | 0,3998 | 745,7 |
| 340 | 0,5717 | 751,6 | 0,4755 | 751,1 | 0,4068 | 750,7 |
| 350 | 0,5814 | 756,6 | 0,4836 | 756,1 | 0,4138 | 755,7 |
| 360 | 0,5910 | 761,5 | 0,4917 | 761,1 | 0,4207 | 760,7 |
| 370 | 0,6006 | 766,5 | 0,4998 | 766,1 | 0,4277 | 765,7 |
| 380 | 0,6102 | 771,5 | 0,5078 | 771,0 | 0,4346 | 770,7 |
| 390 | 0,6198 | 776,5 | 0,5158 | 776,0 | 0,4415 | 775,7 |
| 400 | 0,6294 | 781,5 | 0,5238 | 781,1 | 0,4484 | 780,7 |
| 410 | 0,6390 | 786,5 | 0,5318 | 786,1 | 0,4553 | 785,8 |
| 420 | 0,6485 | 791,5 | 0,5398 | 791,2 | 0,4622 | 790,8 |
| 430 | 0,6581 | 796,5 | 0,5478 | 796,2 | 0,4690 | 795,9 |
| 440 | 0,6677 | 801,6 | 0,5558 | 801,3 | 0,4759 | 801,0 |
| 450 | 0,6772 | 806,7 | 0,5638 | 806,3 | 0,4827 | 806,1 |

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cont.

| | $p = 8,0$ ama (1) | | $p = 9,0$ ama (1) | | $p = 10,0$ ama (1) | |
|---|---|---|---|---|---|---|
| 170 | 0,2452 | 661,5 | | | | |
| 180 | 0,2524 | 667,2 | 0,2225 | 665,5 | 0,1986 | 663,8 |
| 190 | 0,2594 | 672,8 | 0,2290 | 671,3 | 0,2046 | 669,8 |
| 200 | 0,2662 | 678,3 | 0,2353 | 677,0 | 0,2104 | 675,7 |
| 210 | 0,2730 | 683,8 | 0,2414 | 682,6 | 0,2160 | 681,4 |
| 220 | 0,2797 | 689,1 | 0,2474 | 688,0 | 0,2215 | 686,9 |
| 230 | 0,2863 | 694,4 | 0,2533 | 693,4 | 0,2269 | 692,4 |
| 240 | 0,2928 | 699,6 | 0,2591 | 698,7 | 0,2322 | 697,8 |
| 250 | 0,2992 | 704,7 | 0,2649 | 703,9 | 0,2375 | 703,0 |
| 260 | 0,3055 | 709,8 | 0,2706 | 709,1 | 0,2427 | 708,2 |
| 270 | 0,3118 | 714,9 | 0,2762 | 714,2 | 0,2479 | 713,4 |
| 280 | 0,3181 | 720,0 | 0,2818 | 719,3 | 0,2530 | 718,6 |
| 290 | 0,3244 | 725,1 | 0,2874 | 724,4 | 0,2581 | 723,8 |
| 300 | 0,3306 | 730,1 | 0,2930 | 729,5 | 0,2632 | 728,9 |
| 310 | 0,3368 | 735,1 | 0,2986 | 734,6 | 0,2682 | 734,0 |
| 320 | 0,3430 | 740,1 | 0,3042 | 739,6 | 0,2732 | 739,0 |
| 330 | 0,3492 | 745,2 | 0,3097 | 744,6 | 0,2782 | 744,1 |
| 340 | 0,3553 | 750,2 | 0,3152 | 749,7 | 0,2832 | 749,2 |
| 350 | 0,3614 | 755,2 | 0,3207 | 754,7 | 0,2881 | 754,3 |
| 360 | 0,3675 | 760,2 | 0,3261 | 759,8 | 0,2930 | 759,3 |
| 370 | 0,3736 | 765,2 | 0,3316 | 764,8 | 0,2980 | 764,4 |
| 380 | 0,3797 | 770,3 | 0,3370 | 769,9 | 0,3029 | 769,5 |
| 390 | 0,3858 | 775,3 | 0,3424 | 774,9 | 0,3078 | 774,6 |
| 400 | 0,3918 | 780,4 | 0,3478 | 780,0 | 0,3126 | 779,6 |
| 410 | 0,3979 | 785,4 | 0,3532 | 785,1 | 0,3175 | 784,7 |
| 420 | 0,4039 | 790,5 | 0,3586 | 790,2 | 0,3223 | 789,8 |
| 430 | 0,4100 | 795,6 | 0,3640 | 795,2 | 0,3272 | 794,9 |
| 440 | 0,4160 | 800,7 | 0,3694 | 800,3 | 0,3320 | 800,0 |
| 450 | 0,4220 | 805,8 | 0,3747 | 805,5 | 0,3369 | 805,2 |
| | $p = 11,0$ ama (1) | | $p = 12,0$ ama (1) | | $p = 13,0$ ama (1) | |
| 190 | 0,1846 | 668,3 | 0,1677 | 666,8 | | |
| 200 | 0,1900 | 674,3 | 0,1729 | 672,9 | 0,1583 | 671,4 |
| 210 | 0,1952 | 680,2 | 0,1779 | 678,9 | 0,1631 | 677,5 |
| 220 | 0,2003 | 685,9 | 0,1827 | 684,7 | 0,1677 | 683,5 |
| 230 | 0,2053 | 691,4 | 0,1873 | 690,3 | 0,1721 | 689,3 |
| 240 | 0,2102 | 696,8 | 0,1919 | 695,8 | 0,1764 | 694,9 |
| 250 | 0,2151 | 702,2 | 0,1964 | 701,3 | 0,1806 | 700,4 |
| 260 | 0,2199 | 707,5 | 0,2008 | 706,7 | 0,1847 | 705,8 |
| 270 | 0,2246 | 712,7 | 0,2052 | 712,0 | 0,1888 | 711,2 |
| 280 | 0,2293 | 717,9 | 0,2096 | 717,3 | 0,1928 | 716,5 |
| 290 | 0,2340 | 723,1 | 0,2139 | 722,5 | 0,1968 | 721,8 |
| 300 | 0,2386 | 728,3 | 0,2182 | 727,7 | 0,2008 | 727,0 |
| 310 | 0,2432 | 733,4 | 0,2224 | 732,8 | 0,2048 | 732,2 |
| 320 | 0,2478 | 738,5 | 0,2266 | 738,0 | 0,2087 | 737,4 |
| 330 | 0,2524 | 743,6 | 0,2308 | 743,1 | 0,2126 | 742,5 |
| 340 | 0,2569 | 748,7 | 0,2350 | 748,2 | 0,2165 | 747,7 |
| 350 | 0,2614 | 753,8 | 0,2392 | 753,3 | 0,2204 | 752,8 |
| 360 | 0,2659 | 758,9 | 0,2434 | 758,4 | 0,2243 | 758,0 |
| 370 | 0,2704 | 764,0 | 0,2475 | 763,5 | 0,2281 | 763,1 |
| 380 | 0,2749 | 769,1 | 0,2516 | 768,7 | 0,2319 | 768,3 |

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|---|---|---|---|---|---|---|
| 390 | 0,2794 | 774,2 | 0,2557 | 773,8 | 0,2357 | 773,4 |
| 400 | 0,2838 | 779,3 | 0,2598 | 778,9 | 0,2395 | 778,5 |
| 410 | 0,2883 | 784,4 | 0,2639 | 784,0 | 0,2433 | 783,7 |
| 420 | 0,2927 | 789,5 | 0,2680 | 789,1 | 0,2471 | 788,8 |
| 430 | 0,2972 | 794,6 | 0,2721 | 794,3 | 0,2509 | 794,0 |
| 440 | 0,3016 | 799,7 | 0,2762 | 799,4 | 0,2546 | 799,1 |
| 450 | 0,3060 | 804,9 | 0,2802 | 804,6 | 0,2584 | 804,3 |
| | $p = 14,0$ ama (1) | | $p = 15,0$ ama (1) | | $p = 16,0$ ama (1) | |
| 200 | 0,1461 | 669,9 | 0,1353 | 668,4 | | |
| 210 | 0,1506 | 676,2 | 0,1396 | 674,8 | 0,1300 | 673,4 |
| 220 | 0,1549 | 682,3 | 0,1437 | 681,0 | 0,1339 | 679,8 |
| 230 | 0,1590 | 688,2 | 0,1476 | 687,0 | 0,1376 | 685,9 |
| 240 | 0,1630 | 693,9 | 0,1514 | 692,9 | 0,1413 | 691,9 |
| 250 | 0,1670 | 699,5 | 0,1552 | 698,6 | 0,1449 | 697,7 |
| 260 | 0,1709 | 705,0 | 0,1589 | 704,2 | 0,1484 | 703,3 |
| 270 | 0,1747 | 710,4 | 0,1625 | 709,7 | 0,1518 | 708,9 |
| 280 | 0,1785 | 715,8 | 0,1661 | 715,1 | 0,1552 | 714,4 |
| 290 | 0,1823 | 721,1 | 0,1697 | 720,5 | 0,1586 | 719,8 |
| 300 | 0,1860 | 726,4 | 0,1732 | 725,8 | 0,1619 | 725,1 |
| 310 | 0,1897 | 731,6 | 0,1767 | 731,0 | 0,1652 | 730,4 |
| 320 | 0,1934 | 736,8 | 0,1801 | 736,3 | 0,1684 | 735,7 |
| 330 | 0,1970 | 742,0 | 0,1835 | 741,5 | 0,1717 | 741,0 |
| 340 | 0,2007 | 747,2 | 0,1869 | 746,7 | 0,1749 | 746,2 |
| 350 | 0,2043 | 752,4 | 0,1903 | 751,9 | 0,1781 | 751,4 |
| 360 | 0,2079 | 757,6 | 0,1937 | 757,1 | 0,1812 | 756,6 |
| 370 | 0,2115 | 762,7 | 0,1970 | 762,3 | 0,1844 | 761,8 |
| 380 | 0,2150 | 767,8 | 0,2004 | 767,4 | 0,1876 | 767,0 |
| 390 | 0,2186 | 773,0 | 0,2037 | 772,6 | 0,1907 | 772,2 |
| 400 | 0,2221 | 778,1 | 0,2070 | 777,8 | 0,1938 | 777,4 |
| 410 | 0,2257 | 783,3 | 0,2103 | 782,9 | 0,1969 | 782,6 |
| 420 | 0,2292 | 788,4 | 0,2136 | 788,1 | 0,2000 | 787,8 |
| 430 | 0,2327 | 793,6 | 0,2169 | 793,3 | 0,2031 | 793,0 |
| 440 | 0,2362 | 798,8 | 0,2202 | 798,5 | 0,2062 | 798,2 |
| 450 | 0,2397 | 804,0 | 0,2235 | 803,6 | 0,2093 | 803,4 |
| | $p = 17,0$ ama (1) | | $p = 18,0$ ama (1) | | $p = 19,0$ ama (1) | |
| 210 | 0,1214 | 672,0 | 0,1138 | 670,5 | 0,1070 | 669,0 |
| 220 | 0,1252 | 678,5 | 0,1175 | 677,2 | 0,1106 | 675,8 |
| 230 | 0,1289 | 684,8 | 0,1210 | 683,6 | 0,1140 | 682,4 |
| 240 | 0,1324 | 690,9 | 0,1244 | 689,8 | 0,1172 | 688,7 |
| 250 | 0,1358 | 696,8 | 0,1277 | 695,8 | 0,1204 | 694,8 |
| 260 | 0,1391 | 702,5 | 0,1309 | 701,6 | 0,1235 | 700,7 |
| 270 | 0,1424 | 708,1 | 0,1340 | 707,3 | 0,1265 | 706,5 |
| 280 | 0,1456 | 713,6 | 0,1371 | 712,9 | 0,1294 | 712,2 |
| 290 | 0,1488 | 719,1 | 0,1401 | 718,4 | 0,1323 | 717,7 |
| 300 | 0,1520 | 724,5 | 0,1431 | 723,8 | 0,1352 | 723,1 |
| 310 | 0,1551 | 729,8 | 0,1461 | 729,2 | 0,1380 | 728,5 |
| 320 | 0,1582 | 735,2 | 0,1490 | 734,6 | 0,1408 | 733,9 |
| 330 | 0,1612 | 740,5 | 0,1519 | 739,9 | 0,1436 | 739,3 |
| 340 | 0,1643 | 745,7 | 0,1548 | 745,2 | 0,1464 | 744,7 |
| 350 | 0,1673 | 751,0 | 0,1577 | 750,5 | 0,1491 | 750,0 |

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|---|---|---|---|---|---|---|
| 360 | 0,1703 | 756,2 | 0,1606 | 755,7 | 0,1518 | 755,3 |
| 370 | 0,1733 | 761,4 | 0,1634 | 761,0 | 0,1545 | 760,5 |
| 380 | 0,1763 | 766,6 | 0,1662 | 766,2 | 0,1572 | 765,8 |
| 390 | 0,1792 | 771,8 | 0,1690 | 771,4 | 0,1599 | 771,0 |
| 400 | 0,1822 | 777,0 | 0,1718 | 776,6 | 0,1626 | 776,2 |
| 410 | 0,1851 | 782,2 | 0,1746 | 781,9 | 0,1652 | 781,5 |
| 420 | 0,1880 | 787,4 | 0,1774 | 787,1 | 0,1679 | 786,7 |
| 430 | 0,1910 | 792,6 | 0,1801 | 792,3 | 0,1705 | 791,9 |
| 440 | 0,1939 | 797,8 | 0,1829 | 797,5 | 0,1731 | 797,2 |
| 450 | 0,1968 | 803,0 | 0,1857 | 802,7 | 0,1767 | 802,4 |
| | $p$ = 20,0 ama (1) | | $p$ = 21 ama (1) | | $p$ = 22 ama (1) | |
| 220 | 0,1044 | 674,4 | 0,09873 | 673,0 | 0,09355 | 671,5 |
| 230 | 0,1078 | 681,2 | 0,1019 | 679,9 | 0,09676 | 678,6 |
| 240 | 0,1109 | 687,6 | 0,1050 | 686,5 | 0,09981 | 685,3 |
| 250 | 0,1139 | 693,8 | 0,1080 | 692,8 | 0,1026 | 691,8 |
| 260 | 0,1168 | 699,8 | 0,1108 | 698,9 | 0,1053 | 698,0 |
| 270 | 0,1197 | 705,7 | 0,1136 | 704,8 | 0,1080 | 704,0 |
| 280 | 0,1225 | 711,4 | 0,1163 | 710,5 | 0,1106 | 709,8 |
| 290 | 0,1253 | 717,0 | 0,1190 | 716,2 | 0,1132 | 715,5 |
| 300 | 0,1281 | 722,5 | 0,1216 | 721,8 | 0,1158 | 721,2 |
| 310 | 0,1308 | 727,9 | 0,1242 | 727,4 | 0,1183 | 726,8 |
| 320 | 0,1335 | 733,4 | 0,1268 | 732,9 | 0,1208 | 732,3 |
| 330 | 0,1361 | 738,8 | 0,1294 | 738,3 | 0,1232 | 737,7 |
| 340 | 0,1388 | 744,2 | 0,1319 | 743,6 | 0,1256 | 743,1 |
| 350 | 0,1414 | 749,5 | 0,1344 | 749,0 | 0,1280 | 748,5 |
| 360 | 0,1440 | 754,8 | 0,1369 | 754,3 | 0,1304 | 753,9 |
| 370 | 0,1466 | 760,1 | 0,1394 | 759,6 | 0,1328 | 759,2 |
| 380 | 0,1491 | 765,3 | 0,1418 | 764,9 | 0,1351 | 764,5 |
| 390 | 0,1517 | 770,6 | 0,1443 | 770,2 | 0,1375 | 769,8 |
| 400 | 0,1542 | 775,8 | 0,1467 | 775,5 | 0,1398 | 775,1 |
| 410 | 0,1567 | 781,1 | 0,1491 | 780,7 | 0,1421 | 780,4 |
| 420 | 0,1593 | 786,4 | 0,1515 | 786,0 | 0,1444 | 785,7 |
| 430 | 0,1618 | 791,6 | 0,1539 | 791,3 | 0,1467 | 790,9 |
| 440 | 0,1643 | 796,9 | 0,1563 | 796,6 | 0,1490 | 796,2 |
| 450 | 0,1668 | 802,1 | 0,1587 | 801,8 | 0,1513 | 801,5 |
| 460 | 0,1693 | 807,4 | 0,1610 | 807,1 | 0,1536 | 806,8 |
| 470 | 0,1717 | 812,6 | 0,1634 | 812,4 | 0,1558 | 812,1 |
| 480 | 0,1742 | 817,9 | 0,1657 | 817,7 | 0,1581 | 817,4 |
| 490 | 0,1767 | 823,2 | 0,1681 | 823,0 | 0,1603 | 822,7 |
| 500 | 0,1791 | 828,5 | 0,1704 | 828,2 | 0,1626 | 826,0 |
| | $p$ = 23 ama (1) | | $p$ = 24 ama (1) | | $p$ = 25 ama (1) | |
| 220 | 0,08890 | 670,1 | | | | |
| 230 | 0,09196 | 677,3 | 0,08759 | 675,9 | 0,08355 | 674,5 |
| 240 | 0,09487 | 684,1 | 0,09041 | 682,9 | 0,08631 | 681,7 |
| 250 | 0,09765 | 690,7 | 0,09312 | 689,7 | 0,08896 | 688,6 |
| 260 | 0,1003 | 697,0 | 0,09572 | 696,1 | 0,09151 | 695,1 |
| 270 | 0,1029 | 703,1 | 0,09827 | 702,3 | 0,09397 | 701,4 |
| 280 | 0,1055 | 709,0 | 0,1007 | 708,3 | 0,09636 | 707,5 |
| 290 | 0,1080 | 714,8 | 0,1031 | 714,1 | 0,09871 | 713,4 |
| 300 | 0,1104 | 720,5 | 0,1055 | 719,8 | 0,1010 | 719,2 |
| 310 | 0,1128 | 726,1 | 0,1078 | 725,4 | 0,1033 | 724,9 |

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|---|---|---|---|---|---|---|
| 320 | 0,1152 | 731,7 | 0,1101 | 731,0 | 0,1055 | 730,5 |
| 330 | 0,1176 | 737,2 | 0,1124 | 736,6 | 0,1077 | 736,0 |
| 340 | 0,1199 | 742,6 | 0,1147 | 742,1 | 0,1099 | 741,5 |
| 350 | 0,1222 | 748,0 | 0,1169 | 747,5 | 0,1120 | 747,0 |
| 360 | 0,1245 | 753,4 | 0,1191 | 752,9 | 0,1142 | 752,4 |
| 370 | 0,1268 | 758,8 | 0,1213 | 758,3 | 0,1163 | 757,8 |
| 380 | 0,1290 | 764,1 | 0,1235 | 763,7 | 0,1184 | 763,2 |
| 390 | 0,1313 | 769,4 | 0,1257 | 769,0 | 0,1205 | 768,6 |
| 400 | 0,1335 | 774,7 | 0,1278 | 774,3 | 0,1225 | 773,9 |
| 410 | 0,1358 | 780,0 | 0,1299 | 779,6 | 0,1246 | 779,3 |
| 420 | 0,1380 | 785,3 | 0,1321 | 785,0 | 0,1266 | 784,6 |
| 430 | 0,1402 | 790,6 | 0,1342 | 790,3 | 0,1287 | 789,9 |
| 440 | 0,1424 | 795,9 | 0,1363 | 795,6 | 0,1307 | 795,2 |
| 450 | 0,1446 | 801,2 | 0,1384 | 800,9 | 0,1327 | 800,5 |
| 460 | 0,1468 | 806,5 | 0,1405 | 806,2 | 0,1347 | 805,9 |
| 470 | 0,1489 | 811,8 | 0,1426 | 811,5 | 0,1367 | 811,2 |
| 480 | 0,1511 | 817,1 | 0,1447 | 816,8 | 0,1387 | 816,5 |
| 490 | 0,1532 | 822,4 | 0,1467 | 822,1 | 0,1407 | 821,9 |
| 500 | 0,1554 | (1) 827,7 | 0,1488 | (1) 827,4 | 0,1427 | (1) 827,2 |
| | $p = 26$ *ama* | | $p = 27$ *ama* | | $p = 28$ *ama* | |
| 230 | 0,07981 | 673,1 | 0,07634 | 671,7 | 0,07309 | 670,2 |
| 240 | 0,08251 | 680,5 | 0,07900 | 679,2 | 0,07570 | 677,9 |
| 250 | 0,08510 | 687,5 | 0,08153 | 686,3 | 0,07820 | 685,2 |
| 260 | 0,08759 | 694,1 | 0,08396 | 693,1 | 0,08059 | 692,1 |
| 270 | 0,08999 | 700,4 | 0,08631 | 699,6 | 0,08288 | 698,7 |
| 280 | 0,09232 | 706,6 | 0,08858 | 705,8 | 0,08510 | 705,0 |
| 290 | 0,09460 | 712,6 | 0,09079 | 711,9 | 0,08726 | 711,1 |
| 300 | 0,09683 | 718,4 | 0,09295 | 717,8 | 0,08937 | 717,1 |
| 310 | 0,09901 | 724,2 | 0,09508 | 723,6 | 0,09144 | 722,9 |
| 320 | 0,1012 | 729,9 | 0,09718 | 729,3 | 0,09348 | 728,6 |
| 330 | 0,1033 | 735,5 | 0,09925 | 734,9 | 0,09549 | 734,3 |
| 340 | 0,1054 | 741,0 | 0,1013 | 740,5 | 0,09747 | 739,9 |
| 350 | 0,1075 | 746,5 | 0,1033 | 746,0 | 0,09942 | 745,5 |
| 360 | 0,1095 | 752,0 | 0,1053 | 751,5 | 0,1013 | 751,0 |
| 370 | 0,1116 | 757,4 | 0,1073 | 756,9 | 0,1033 | 756,5 |
| 380 | 0,1136 | 762,8 | 0,1092 | 762,4 | 0,1052 | 761,9 |
| 390 | 0,1156 | 768,2 | 0,1112 | 767,8 | 0,1071 | 767,4 |
| 400 | 0,1176 | 773,5 | 0,1131 | 773,2 | 0,1089 | 772,8 |
| 410 | 0,1196 | 778,9 | 0,1150 | 778,5 | 0,1108 | 778,2 |
| 420 | 0,1216 | 784,2 | 0,1170 | 783,9 | 0,1126 | 783,5 |
| 430 | 0,1236 | 789,6 | 0,1189 | 789,2 | 0,1145 | 788,9 |
| 440 | 0,1255 | 794,9 | 0,1208 | 794,6 | 0,1163 | 794,3 |
| 450 | 0,1275 | 800,3 | 0,1226 | 799,9 | 0,1181 | 799,6 |
| 460 | 0,1294 | 805,6 | 0,1245 | 805,3 | 0,1199 | 805,0 |
| 470 | 0,1314 | 810,9 | 0,1264 | 810,6 | 0,1217 | 810,4 |
| 480 | 0,1333 | 816,3 | 0,1282 | 816,0 | 0,1235 | 815,7 |
| 490 | 0,1352 | 821,6 | 0,1301 | 821,3 | 0,1253 | 821,1 |
| 500 | 0,1371 | (1) 827,0 | 0,1319 | (1) 826,7 | 0,1271 | (1) 826,4 |
| | $p = 29$ *ama* | | $p = 30$ *ama* | | $p = 31$ *ama* | |
| 240 | 0,07263 | 676,5 | 0,06976 | 675,2 | 0,06708 | 673,8 |
| 250 | 0,07510 | 684,0 | 0,07220 | 682,8 | 0,06947 | 681,6 |
| 260 | 0,07744 | 691,1 | 0,07450 | 690,0 | 0,07174 | 688,9 |
| 270 | 0,07969 | 697,8 | 0,07670 | 696,8 | 0,07391 | 695,8 |
| 280 | 0,08186 | 704,2 | 0,07883 | 703,3 | 0,07599 | 702,4 |

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|---|---|---|---|---|---|---|
| 290 | 0,08397 | 710,3 | 0,08089 | 709,5 | 0,07801 | 708,7 |
| 300 | 0,08603 | 716,3 | 0,08290 | 715,6 | 0,07997 | 714,9 |
| 310 | 0,08804 | 722,2 | 0,08486 | 721,6 | 0,08189 | 720,9 |
| 320 | 0,09002 | 728,0 | 0,08679 | 727,4 | 0,08377 | 726,8 |
| 330 | 0,09197 | 733,7 | 0,08869 | 733,2 | 0,08562 | 732,6 |
| 340 | 0,09389 | 739,3 | 0,09056 | 738,9 | 0,08744 | 738,3 |
| 350 | 0,09579 | 744,9 | 0,09240 | 744,5 | 0,08924 | 743,9 |
| 360 | 0,09767 | 750,5 | 0,09423 | 750,1 | 0,09102 | 749,5 |
| 370 | 0,09953 | 756,0 | 0,09604 | 755,6 | 0,09278 | 755,1 |
| 380 | 0,1014 | 761,5 | 0,09783 | 761,1 | 0,09452 | 760,6 |
| 390 | 0,1032 | 766,9 | 0,09961 | 766,5 | 0,09625 | 766,1 |
| 400 | 0,1050 | 772,4 | 0,1014 | 772,0 | 0,09796 | 771,6 |
| 410 | 0,1068 | 777,8 | 0,1031 | 777,4 | 0,09966 | 777,0 |
| 420 | 0,1086 | 783,2 | 0,1049 | 782,8 | 0,1014 | 782,5 |
| 430 | 0,1104 | 788,6 | 0,1066 | 788,2 | 0,1030 | 787,9 |
| 440 | 0,1122 | 794,0 | 0,1083 | 793,6 | 0,1047 | 793,3 |
| 450 | 0,1139 | 799,3 | 0,1100 | 799,0 | 0,1064 | 798,7 |
| 460 | 0,1157 | 804,7 | 0,1117 | 804,4 | 0,1080 | 804,1 |
| 470 | 0,1174 | 810,1 | 0,1134 | 809,8 | 0,1097 | 809,5 |
| 480 | 0,1192 | 815,4 | 0,1151 | 815,2 | 0,1113 | 814,9 |
| 490 | 0,1209 | 820,8 | 0,1168 | 820,6 | 0,1129 | 820,3 |
| 500 | 0,1226 | (1) 826,2 | 0,1185 | (1) 825,9 | 0,1146 | (1) 825,7 |
| | $p = 32$ ama | | $p = 33$ ama | | $p = 34$ ama | |
| 240 | 0,06455 | 672,4 | 0,06218 | 671,1 | 0,05934 | 669,8 |
| 250 | 0,06692 | 680,3 | 0,06451 | 679,1 | 0,06224 | 677,9 |
| 260 | 0,06916 | 687,8 | 0,06672 | 686,7 | 0,06442 | 685,5 |
| 270 | 0,07129 | 694,8 | 0,06882 | 693,9 | 0,06649 | 692,8 |
| 280 | 0,07333 | 701,5 | 0,07083 | 700,7 | 0,06847 | 699,8 |
| 290 | 0,07531 | 707,9 | 0,07277 | 707,2 | 0,07037 | 706,4 |
| 300 | 0,07723 | 714,1 | 0,07465 | 713,4 | 0,07222 | 712,7 |
| 310 | 0,07910 | 720,2 | 0,07648 | 719,5 | 0,07402 | 718,9 |
| 320 | 0,08094 | 726,1 | 0,07827 | 725,5 | 0,07577 | 724,9 |
| 330 | 0,08275 | 732,0 | 0,08003 | 731,3 | 0,07749 | 730,8 |
| 340 | 0,08453 | 737,7 | 0,08177 | 737,1 | 0,07919 | 736,6 |
| 350 | 0,08628 | 743,4 | 0,08349 | 742,9 | 0,08087 | 742,4 |
| 360 | 0,08801 | 749,0 | 0,08518 | 748,6 | 0,08252 | 748,2 |
| 370 | 0,08972 | 754,6 | 0,08685 | 754,2 | 0,08414 | 753,8 |
| 380 | 0,09142 | 760,2 | 0,08850 | 759,8 | 0,08575 | 759,3 |
| 390 | 0,09310 | 765,7 | 0,09014 | 765,3 | 0,08735 | 764,8 |
| 400 | 0,09477 | 771,2 | 0,09176 | 770,8 | 0,08893 | 770,4 |
| 410 | 0,09641 | 776,6 | 0,09337 | 776,2 | 0,09050 | 775,9 |
| 420 | 0,09807 | 782,1 | 0,09497 | 781,7 | 0,09206 | 781,4 |
| 430 | 0,09969 | 787,5 | 0,09656 | 787,2 | 0,09361 | 786,8 |
| 440 | 0,1013 | 793,0 | 0,09814 | 792,6 | 0,09514 | 792,3 |
| 450 | 0,1029 | 798,4 | 0,09971 | 798,1 | 0,09667 | 797,8 |
| 460 | 0,1045 | 803,8 | 0,1013 | 803,5 | 0,09819 | 803,2 |
| 470 | 0,1061 | 809,2 | 0,1028 | 808,9 | 0,09970 | 808,6 |
| 480 | 0,1077 | 814,6 | 0,1044 | 814,3 | 0,1012 | 814,1 |
| 490 | 0,1093 | 820,0 | 0,1059 | 819,8 | 0,1027 | 819,5 |
| 500 | 0,1109 | (1) 825,4 | 0,1074 | (1) 825,2 | 0,1042 | (1) 824,9 |
| | $p = 35$ ama | | $p = 36$ ama | | $p = 37$ ama | |
| 250 | 0,06010 | 676,5 | 0,05806 | 675,1 | 0,05613 | 673,8 |
| 260 | 0,06226 | 684,4 | 0,06020 | 683,2 | 0,05826 | 682,0 |
| 270 | 0,06430 | 691,8 | 0,06222 | 690,8 | 0,06025 | 689,7 |
| 280 | 0,06625 | 698,8 | 0,06414 | 697,9 | 0,06214 | 697,0 |
| 290 | 06812 | 705,5 | 0,06598 | 704,7 | 0,06396 | 703,9 |

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|---|---|---|---|---|---|---|
| 300 | 0,06993 | 711,9 | 0,06776 | 711,2 | 0,06571 | 710,4 |
| 310 | 0,07169 | 718,1 | 0,06949 | 717,5 | 0,06741 | 716,7 |
| 320 | 0,07341 | 724,2 | 0,07118 | 723,6 | 0,06906 | 722,9 |
| 330 | 0,07510 | 730,2 | 0,07283 | 729,6 | 0,07068 | 729,0 |
| 340 | 0,07676 | 736,0 | 0,07446 | 735,5 | 0,07227 | 734,9 |
| 350 | 0,07839 | 741,8 | 0,07605 | 741,3 | 0,07384 | 740,8 |
| 360 | 0,08000 | 747,5 | 0,07763 | 747,1 | 0,07538 | 746,6 |
| 370 | 0,08159 | 753,2 | 0,07918 | 752,8 | 0,07690 | 752,3 |
| 380 | 0,08316 | 758,8 | 0,08072 | 758,4 | 0,07840 | 758,0 |
| 390 | 0,08472 | 764,4 | 0,08224 | 764,0 | 0,07989 | 763,6 |
| 400 | 0,08626 | 770,0 | 0,08375 | 769,6 | 0,08136 | 769,2 |
| 410 | 0,08779 | 775,5 | 0,08524 | 775,1 | 0,08282 | 774,7 |
| 420 | 0,08931 | 781,0 | 0,08672 | 780,6 | 0,08427 | 780,3 |
| 430 | 0,09082 | 786,5 | 0,08819 | 786,1 | 0,08571 | 785,8 |
| 440 | 0,09232 | 792,0 | 0,08965 | 791,6 | 0,08713 | 791,3 |
| 450 | 0,09381 | 797,4 | 0,09111 | 797,1 | 0,08855 | 796,8 |
| 460 | 0,09529 | 802,9 | 0,09255 | 802,6 | 0,08996 | 802,3 |
| 470 | 0,09676 | 808,3 | 0,09398 | 808,1 | 0,09136 | 807,8 |
| 480 | 0,09823 | 813,8 | 0,09541 | 813,5 | 0,09275 | 813,2 |
| 490 | 0,09969 | 819,2 | 0,09683 | 819,0 | 0,09414 | 818,7 |
| 500 | 0,1011 | 824,7 | 0,09824 | 824,4 | 0,09552 | 824,2 |
| | $p = 38$ ama (1) | | $p = 39$ ama (1) | | $p = 40$ ama (1) | |
| 250 | 0,05430 | 672,5 | 0,05257 | 671,1 | 0,05090 | 669,7 |
| 260 | 0,05640 | 680,9 | 0,05466 | 679,6 | 0,05297 | 678,4 |
| 270 | 0,05838 | 688,7 | 0,05662 | 687,6 | 0,05491 | 686,5 |
| 280 | 0,06023 | 696,0 | 0,05847 | 695,1 | 0,05675 | 694,1 |
| 290 | 0,06204 | 702,9 | 0,06023 | 702,1 | 0,05849 | 701,2 |
| 300 | 0,06376 | 709,5 | 0,06192 | 708,8 | 0,06016 | 708,0 |
| 310 | 0,06543 | 716,0 | 0,06356 | 715,3 | 0,06178 | 714,6 |
| 320 | 0,06706 | 722,3 | 0,06516 | 721,6 | 0,06335 | 720,9 |
| 330 | 0,06865 | 728,4 | 0,06672 | 727,7 | 0,06488 | 727,1 |
| 340 | 0,07021 | 734,3 | 0,06825 | 733,7 | 0,06638 | 733,2 |
| 350 | 0,07174 | 740,2 | 0,06975 | 739,6 | 0,06786 | 739,1 |
| 360 | 0,07325 | 746,0 | 0,07123 | 745,5 | 0,06931 | 745,0 |
| 370 | 0,07474 | 751,8 | 0,07269 | 751,3 | 0,07074 | 750,8 |
| 380 | 0,07621 | 757,5 | 0,07413 | 757,0 | 0,07215 | 756,6 |
| 390 | 0,07767 | 763,2 | 0,07556 | 762,7 | 0,07355 | 762,3 |
| 400 | 0,07911 | 768,8 | 0,07697 | 768,4 | 0,07493 | 768,0 |
| 410 | 0,08054 | 774,4 | 0,07836 | 774,0 | 0,07630 | 773,6 |
| 420 | 0,08195 | 779,9 | 0,07974 | 779,5 | 0,07765 | 779,2 |
| 430 | 0,08335 | 785,4 | 0,08111 | 785,1 | 0,07899 | 784,8 |
| 440 | 0,08474 | 791,0 | 0,08247 | 790,6 | 0,08032 | 790,3 |
| 450 | 0,08613 | 796,5 | 0,08382 | 796,2 | 0,08164 | 795,9 |
| 460 | 0,08751 | 802,0 | 0,08517 | 801,7 | 0,08295 | 801,4 |
| 470 | 0,08887 | 807,5 | 0,08651 | 807,2 | 0,08426 | 806,9 |
| 480 | 0,09023 | 812,9 | 0,08784 | 812,7 | 0,08556 | 812,4 |
| 490 | 0,09158 | 818,4 | 0,08916 | 818,2 | 0,08685 | 817,9 |
| 500 | 0,09293 | 823,9 | 0,09047 | 823,6 | 0,08814 | 823,4 |
| 510 | 0,09427 | 829,4 | 0,09178 | 829,1 | 0,08942 | 828,9 |
| 520 | 0,09560 | 834,8 | 0,09308 | 834,6 | 0,09069 | 834,4 |
| 530 | 0,09693 | 840,3 | 0,09438 | 840,1 | 0,09196 | 839,8 |
| 540 | 0,09826 | 845,8 | 0,09568 | 845,5 | 0,09322 | 845,3 |
| 550 | 0,09968 | 851,2 | 0,09697 | 851,0 | 0,09448 | 850,8 |

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| | $p = 42$ ama [1] | | $p = 44$ ama [1] | | $p = 46$ ama [1] | |
|---|---|---|---|---|---|---|
| 260 | 0,04985 | 675,8 | 0,04699 | 673,2 | 0,04439 | 670,5 |
| 270 | 0,05177 | 684,2 | 0,04883 | 681,9 | 0,04625 | 679,5 |
| 280 | 0,05356 | 692,1 | 0,05065 | 690,0 | 0,04799 | 687,9 |
| 290 | 0,05526 | 699,5 | 0,05232 | 697,6 | 0,04963 | 695,7 |
| 300 | 0,05689 | 706,5 | 0,05392 | 704,8 | 0,05119 | 703,1 |
| 310 | 0,05846 | 713,2 | 0,05544 | 711,6 | 0,05269 | 710,1 |
| 320 | 0,05998 | 719,6 | 0,05692 | 718,2 | 0,05413 | 716,8 |
| 330 | 0,06146 | 725,9 | 0,05836 | 724,6 | 0,05553 | 723,3 |
| 340 | 0,06292 | 732,0 | 0,05977 | 730,8 | 0,05689 | 729,6 |
| 350 | 0,06435 | 738,0 | 0,06115 | 736,9 | 0,05823 | 735,8 |
| 360 | 0,06575 | 744,0 | 0,06250 | 742,9 | 0,05954 | 741,9 |
| 370 | 0,06712 | 749,9 | 0,06343 | 748,9 | 0,06083 | 747,9 |
| 380 | 0,06848 | 755,7 | 0,06514 | 754,8 | 0,06209 | 753,8 |
| 390 | 0,06982 | 761,4 | 0,06643 | 760,6 | 0,06333 | 759,7 |
| 400 | 0,07114 | 767,1 | 0,06771 | 766,3 | 0,06456 | 765,5 |
| 410 | 0,07245 | 772,8 | 0,06897 | 772,0 | 0,06578 | 771,2 |
| 420 | 0,07375 | 778,4 | 0,07022 | 777,7 | 0,06699 | 776,9 |
| 430 | 0,07504 | 784,0 | 0,07146 | 783,4 | 0,06818 | 782,6 |
| 440 | 0,07632 | 789,6 | 0,07268 | 789,0 | 0,06936 | 788,3 |
| 450 | 0,07759 | 795,2 | 0,07390 | 794,6 | 0,07053 | 793,9 |
| 460 | 0,07885 | 800,7 | 0,07511 | 800,1 | 0,07169 | 799,5 |
| 470 | 0,08010 | 806,3 | 0,07631 | 805,7 | 0,07284 | 805,1 |
| 480 | 0,08134 | 811,8 | 0,07750 | 811,3 | 0,07399 | 810,7 |
| 490 | 0,08257 | 817,4 | 0,07868 | 816,8 | 0,07513 | 816,3 |
| 500 | 0,08380 | 822,9 | 0,07986 | 822,3 | 0,07627 | 821,9 |
| 510 | 0,08502 | 828,4 | 0,08104 | 827,9 | 0,07740 | 827,4 |
| 520 | 0,08624 | 833,9 | 0,08221 | 833,4 | 0,07852 | 832,9 |
| 530 | 0,08746 | 839,4 | 0,08337 | 838,9 | 0,07963 | 838,5 |
| 540 | 0,08867 | 844,9 | 0,08453 | 844,4 | 0,08074 | 844,0 |
| 550 | 0,08987 | 850,4 | 0,08568 | 850,0 | 0,08185 | 849,5 |
| | $p = 48$ ama [1] | | $p = 50$ ama [1] | | $p = 52$ ama [1] | |
| 270 | 0,04381 | 677,1 | 0,04157 | 674,7 | 0,03949 | 672,0 |
| 280 | 0,04554 | 685,8 | 0,04327 | 683,6 | 0,04117 | 681,3 |
| 290 | 0,04716 | 693,9 | 0,04486 | 691,9 | 0,04275 | 689,9 |
| 300 | 0,04869 | 701,4 | 0,04637 | 699,7 | 0,04424 | 697,9 |
| 310 | 0,05015 | 708,5 | 0,04781 | 707,0 | 0,04565 | 705,4 |
| 320 | 0,05156 | 715,3 | 0,04919 | 714,0 | 0,04700 | 712,5 |
| 330 | 0,05292 | 721,9 | 0,05052 | 720,7 | 0,04830 | 719,3 |
| 340 | 0,05424 | 728,4 | 0,05181 | 727,2 | 0,04956 | 725,9 |
| 350 | 0,05555 | 734,7 | 0,05307 | 733,6 | 0,05079 | 732,4 |
| 360 | 0,05682 | 740,8 | 0,05431 | 739,8 | 0,05200 | 738,7 |
| 370 | 0,05806 | 746,9 | 0,05552 | 745,9 | 0,05318 | 744,9 |
| 380 | 0,05928 | 752,9 | 0,05671 | 751,9 | 0,05433 | 751,0 |
| 390 | 0,06050 | 758,9 | 0,05788 | 757,9 | 0,05546 | 757,0 |
| 400 | 0,06169 | 764,7 | 0,05903 | 763,8 | 0,05658 | 762,9 |
| 410 | 0,06286 | 770,4 | 0,06017 | 769,6 | 0,05769 | 768,8 |
| 420 | 0,06402 | 776,2 | 0,06130 | 775,4 | 0,05878 | 774,7 |
| 430 | 0,06517 | 781,9 | 0,06241 | 781,2 | 0,05986 | 780,5 |
| 440 | 0,06631 | 787,6 | 0,05351 | 786,9 | 0,06092 | 786,2 |
| 450 | 0,06744 | 793,3 | 0,06460 | 792,6 | 0,06193 | 791,9 |
| 460 | 0,06856 | 798,9 | 0,06568 | 798,2 | 0,06303 | 797,6 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| 470 | 0,06967 | 804,5 | 0,06676 | 803,9 | 0,06406 | 803,3 |
| 480 | 0,07078 | 810,1 | 0,06782 | 809,6 | 0,06509 | 809,0 |
| 490 | 0,07188 | 815,7 | 0,06888 | 815,2 | 0,06611 | 814,6 |
| 500 | 0,07297 | 821,3 | 0,06993 | 820,8 | 0,06713 | 820,3 |
| 510 | 0,07405 | 826,9 | 0,07098 | 826,4 | 0,06814 | 825,9 |
| 520 | 0,07513 | 832,4 | 0,07202 | 832,0 | 0,06915 | 831,5 |
| 530 | 0,07621 | 838,0 | 0,07305 | 837,5 | 0,07015 | 837,1 |
| 540 | 0,07728 | 843,6 | 0,07408 | 843,1 | 0,07114 | 842,7 |
| 550 | 0,07834 | 849,1 | 0,07511 | 848,7 | 0,07213 | 848,3 |
| | (1) $p = 54$ ama | | (1) $p = 56$ ama | | (1) $p = 58$ ama | |
| 270 | 0,03754 | 669,3 | 0,03571 | 666,6 | | |
| 280 | 0,03922 | 679,0 | 0,03739 | 676,5 | 0,03566 | 674,0 |
| 290 | 0,04078 | 687,8 | 0,03895 | 685,6 | 0,03723 | 683,5 |
| 300 | 0,04225 | 696,0 | 0,04041 | 694,1 | 0,03868 | 692,2 |
| 310 | 0,04364 | 703,7 | 0,04178 | 702,0 | 0,04004 | 700,3 |
| 320 | 0,04497 | 711,0 | 0,04308 | 709,4 | 0,04132 | 707,9 |
| 330 | 0,04625 | 717,9 | 0,04433 | 716,5 | 0,04256 | 715,1 |
| 340 | 0,04748 | 724,6 | 0,04555 | 723,4 | 0,04374 | 722,0 |
| 350 | 0,04868 | 731,2 | 0,04672 | 730,0 | 0,04489 | 728,8 |
| 360 | 0,04985 | 737,6 | 0,04787 | 736,5 | 0,04601 | 735,4 |
| 370 | 0,05100 | 743,9 | 0,04899 | 742,8 | 0,04710 | 741,8 |
| 380 | 0,05213 | 750,0 | 0,05009 | 749,0 | 0,04817 | 748,1 |
| 390 | 0,05323 | 756,1 | 0,05116 | 755,1 | 0,04922 | 754,3 |
| 400 | 0,05432 | 762,1 | 0,05221 | 761,2 | 0,05025 | 760,4 |
| 410 | 0,05539 | 768,0 | 0,05325 | 767,2 | 0,05126 | 766,4 |
| 420 | 0,05645 | 773,9 | 0,05428 | 773,1 | 0,05226 | 772,4 |
| 430 | 0,05749 | 779,7 | 0,05530 | 779,0 | 0,05325 | 778,3 |
| 440 | 0,05852 | 785,5 | 0,05630 | 784,8 | 0,05423 | 784,2 |
| 450 | 0,05954 | 791,3 | 0,05729 | 790,6 | 0,05520 | 790,0 |
| 460 | 0,06056 | 797,0 | 0,05827 | 796,4 | 0,05615 | 795,7 |
| 470 | 0,06157 | 802,7 | 0,05925 | 802,1 | 0,05709 | 801,5 |
| 480 | 0,06257 | 808,4 | 0,06022 | 807,8 | 0,05803 | 807,2 |
| 490 | 0,06356 | 814,0 | 0,06118 | 813,5 | 0,05896 | 813,0 |
| 500 | 0,06454 | 819,7 | 0,06213 | 819,2 | 0,05938 | 818,7 |
| 510 | 0,06552 | 825,4 | 0,06308 | 824,9 | 0,06080 | 824,4 |
| 520 | 0,06649 | 831,0 | 0,06402 | 830,5 | 0,06171 | 830,0 |
| 530 | 0,06745 | 836,7 | 0,06495 | 836,2 | 0,06262 | 835,7 |
| 540 | 0,06841 | 842,3 | 0,06588 | 841,8 | 0,06352 | 841,3 |
| 550 | 0,06937 | 847,9 | 0,06681 | 847,4 | 0,06442 | 847,0 |
| | (1) $p = 60$ ama | | (1) $p = 62$ ama | | (1) $p = 64$ ama | |
| 280 | 0,03405 | 671,2 | 0,03252 | 668,5 | 0,03111 | 665,9 |
| 290 | 0,03562 | 681,3 | 0,03409 | 679,0 | 0,03267 | 676,6 |
| 300 | 0,03705 | 690,3 | 0,03553 | 688,3 | 0,03409 | 686,2 |
| 310 | 0,03840 | 698,6 | 0,03687 | 696,8 | 0,03542 | 695,0 |
| 320 | 0,03967 | 706,4 | 0,03813 | 704,7 | 0,03666 | 703,1 |
| 330 | 0,04088 | 713,8 | 0,03932 | 712,2 | 0,03785 | 710,7 |
| 340 | 0,04204 | 720,8 | 0,04046 | 719,4 | 0,03898 | 718,0 |
| 350 | 0,04316 | 727,6 | 0,04157 | 726,4 | 0,04007 | 725,1 |
| 360 | 0,04426 | 734,2 | 0,04265 | 733,1 | 0,04113 | 732,0 |
| 370 | 0,04534 | 740,7 | 0,04370 | 739,7 | 0,04216 | 738,6 |

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|---|---|---|---|---|---|---|
| 380 | 0,04639 | 747,1 | 0,04472 | 746,1 | 0,04316 | 745,1 |
| 390 | 0,04741 | 753,3 | 0,04572 | 752,4 | 0,04414 | 751,5 |
| 400 | 0,04842 | 759,5 | 0,04670 | 758,6 | 0,04510 | 757,7 |
| 410 | 0,04941 | 765,6 | 0,04767 | 764,7 | 0,04604 | 763,9 |
| 420 | 0,05038 | 771,6 | 0,04862 | 770,8 | 0,04697 | 770,0 |
| 430 | 0,05134 | 777,5 | 0,04955 | 776,8 | 0,04788 | 776,0 |
| 440 | 0,05229 | 783,4 | 0,05048 | 782,7 | 0,04878 | 782,0 |
| 450 | 0,05323 | 789,3 | 0,05140 | 788,6 | 0,04967 | 787,9 |
| 460 | 0,05416 | 795,1 | 0,05230 | 794,5 | 0,05056 | 793,8 |
| 470 | 0,05508 | 800,9 | 0,05320 | 800,3 | 0,05143 | 799,7 |
| 480 | 0,05599 | 806,7 | 0,05409 | 806,1 | 0,05230 | 805,5 |
| 490 | 0,05689 | 812,5 | 0,05496 | 811,9 | 0,05315 | 811,3 |
| 500 | 0,05779 | 818,2 | 0,05583 | 817,7 | 0,05400 | 817,1 |
| 510 | 0,05868 | 823,9 | 0,05670 | 823,4 | 0,05484 | 822,8 |
| 520 | 0,05957 | 829,5 | 0,05756 | 829,1 | 0,05568 | 828,6 |
| 530 | 0,06045 | 835,2 | 0,05841 | 834,8 | 0,05651 | 834,3 |
| 540 | 0,06132 | 840,9 | 0,05926 | 840,4 | 0,05733 | 840,0 |
| 550 | 0,06219 | 846,5 | 0,06011 | 846,1 | 0,05815 | 845,7 |
| | $p = 66$ ama (1) | | $p = 68$ ama (1) | | $p = 70$ ama (1) | |
| 290 | 0,03131 | 674,1 | 0,03002 | 671,5 | 0,02880 | 668,9 |
| 300 | 0,03274 | 684,1 | 0,03146 | 681,9 | 0,03025 | 679,6 |
| 310 | 0,03406 | 693,1 | 0,03278 | 691,2 | 0,03156 | 689,2 |
| 320 | 0,03530 | 701,4 | 0,03401 | 699,7 | 0,03278 | 698,0 |
| 330 | 0,03647 | 709,2 | 0,03517 | 707,7 | 0,03393 | 706,2 |
| 340 | 0,03758 | 716,7 | 0,03627 | 715,3 | 0,03502 | 713,9 |
| 350 | 0,03865 | 723,9 | 0,03732 | 722,6 | 0,03606 | 721,3 |
| 360 | 0,03969 | 730,8 | 0,03834 | 729,6 | 0,03706 | 728,4 |
| 370 | 0,04070 | 737,5 | 0,03933 | 736,4 | 0,03804 | 735,3 |
| 380 | 0,04168 | 744,1 | 0,04030 | 743,1 | 0,03899 | 742,0 |
| 390 | 0,04264 | 750,5 | 0,04124 | 749,7 | 0,03992 | 748,7 |
| 400 | 0,04359 | 756,8 | 0,04216 | 756,0 | 0,04082 | 755,1 |
| 410 | 0,04451 | 763,0 | 0,04306 | 762,2 | 0,04171 | 761,4 |
| 420 | 0,04542 | 769,2 | 0,04395 | 768,4 | 0,04258 | 767,6 |
| 430 | 0,04631 | 775,3 | 0,04483 | 774,5 | 0,04343 | 773,8 |
| 440 | 0,04719 | 781,3 | 0,04569 | 780,6 | 0,04427 | 779,9 |
| 450 | 0,04806 | 787,3 | 0,04654 | 786,6 | 0,04510 | 785,9 |
| 460 | 0,04892 | 793,2 | 0,04738 | 792,6 | 0,04592 | 791,8 |
| 470 | 0,04977 | 799,1 | 0,04821 | 798,5 | 0,04673 | 797,8 |
| 480 | 0,05061 | 805,0 | 0,04903 | 804,4 | 0,04753 | 803,8 |
| 490 | 0,05144 | 810,8 | 0,04984 | 810,2 | 0,04833 | 809,7 |
| 500 | 0,05227 | 816,6 | 0,05065 | 816,0 | 0,04912 | 815,5 |
| 510 | 0,05309 | 822,4 | 0,05145 | 821,8 | 0,04990 | 821,3 |
| 520 | 0,05391 | 828,1 | 0,05224 | 827,6 | 0,05067 | 827,1 |
| 530 | 0,05472 | 833,8 | 0,05303 | 833,3 | 0,05144 | 832,9 |
| 540 | 0,05552 | 839,5 | 0,05381 | 839,1 | 0,05220 | 838,7 |
| 550 | 0,05632 | 845,2 | 0,05459 | 844,8 | 0,05296 | 844,4 |
| | $p = 72$ ama (1) | | $p = 74$ ama (1) | | $p = 76$ ama (1) | |
| 290 | 0,02763 | 666,2 | 0,02652 | 663,2 | | |
| 300 | 0,02909 | 677,3 | 0,02799 | 675,0 | 0,02694 | 672,6 |
| 310 | 0,03040 | 687,3 | 0,02931 | 685,3 | 0,02825 | 683,2 |
| 320 | 0,03162 | 696,3 | 0,03052 | 694,5 | 0,02946 | 692,6 |
| 330 | 0,03276 | 704,6 | 0,03165 | 703,0 | 0,03059 | 701,3 |

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|---|---|---|---|---|---|---|
| 340 | 0,03384 | 712,4 | 0,03272 | 711,0 | 0,03166 | 709,5 |
| 350 | 0,03487 | 719,9 | 0,03374 | 718,6 | 0,03267 | 717,3 |
| 360 | 0,03586 | 727,2 | 0,03472 | 725,9 | 0,03364 | 724,7 |
| 370 | 0,03682 | 734,2 | 0,03566 | 733,0 | 0,03457 | 731,9 |
| 380 | 0,03775 | 741,0 | 0,03658 | 739,9 | 0,03547 | 738,9 |
| 390 | 0,03866 | 747,6 | 0,03748 | 746,6 | 0,03635 | 745,7 |
| 400 | 0,03955 | 754,1 | 0,03835 | 753,2 | 0,03721 | 752,3 |
| 410 | 0,04042 | 760,5 | 0,03920 | 759,7 | 0,03805 | 758,8 |
| 420 | 0,04127 | 766,8 | 0,04003 | 766,0 | 0,03887 | 765,2 |
| 430 | 0,04211 | 773,0 | 0,04085 | 772,2 | 0,03967 | 771,5 |
| 440 | 0,04293 | 779,1 | 0,04166 | 778,4 | 0,04046 | 777,7 |
| 450 | 0,04374 | 785,2 | 0,04246 | 784,5 | 0,04124 | 783,9 |
| 460 | 0,04456 | 791,2 | 0,04325 | 790,6 | 0,04201 | 790,0 |
| 470 | 0,04534 | 797,2 | 0,04402 | 796,6 | 0,04277 | 796,0 |
| 480 | 0,04612 | 803,2 | 0,04479 | 802,6 | 0,04352 | 802,0 |
| 490 | 0,04690 | 809,1 | 0,04555 | 808,5 | 0,04426 | 807,9 |
| 500 | 0,04767 | 815,0 | 0,04630 | 814,4 | 0,04500 | 813,9 |
| 510 | 0,04843 | 820,8 | 0,04704 | 820,3 | 0,04573 | 819,8 |
| 520 | 0,04919 | 826,6 | 0,04778 | 826,1 | 0,04645 | 825,6 |
| 530 | 0,04994 | 832,4 | 0,04852 | 831,9 | 0,04717 | 831,5 |
| 540 | 0,05068 | 838,2 | 0,04925 | 837,7 | 0,04768 | 837,3 |
| 550 | 0,05142 | (1) 843,9 | 0,04997 | (1) 843,5 | 0,04859 | (1) 843,1 |

| | *p* = 78 *ama* | | *p* = 80 *ama* | | *p* = 82 *ama.* | |
|---|---|---|---|---|---|---|
| 300 | 0,02593 | 670,0 | 0,02497 | 667,4 | 0,02404 | 664,7 |
| 310 | 0,02726 | 681,0 | 0,02631 | 678,9 | 0,02540 | 676,6 |
| 320 | 0,02847 | 690,8 | 0,02752 | 688,8 | 0,02661 | 686,9 |
| 330 | 0,02959 | 699,7 | 0,02864 | 697,9 | 0,02773 | 696,3 |
| 340 | 0,03064 | 708,0 | 0,02968 | 706,5 | 0,02877 | 705,0 |
| 350 | 0,03164 | 715,9 | 0,03067 | 714,6 | 0,02975 | 713,2 |
| 360 | 0,03260 | 723,5 | 0,03162 | 722,3 | 0,03069 | 720,9 |
| 370 | 0,03352 | 730,8 | 0,03254 | 729,6 | 0,03159 | 728,4 |
| 380 | 0,03441 | 737,8 | 0,03342 | 736,7 | 0,03246 | 735,6 |
| 390 | 0,03528 | 744,7 | 0,03427 | 743,6 | 0,03330 | 742,6 |
| 400 | 0,03613 | 751,4 | 0,03510 | 750,4 | 0,03412 | 749,3 |
| 410 | 0,03695 | 757,9 | 0,03591 | 757,0 | 0,03491 | 756,0 |
| 420 | 0,03776 | 764,3 | 0,03670 | 763,5 | 0,03570 | 762,6 |
| 430 | 0,03855 | 770,7 | 0,03748 | 769,9 | 0,03646 | 769,1 |
| 440 | 0,03943 | 777,0 | 0,03824 | 776,2 | 0,03721 | 775,5 |
| 450 | 0,04009 | 783,2 | 0,03899 | 782,4 | 0,03795 | 781,8 |
| 460 | 0,04084 | 789,3 | 0,03973 | 788,6 | 0,03868 | 788,0 |
| 470 | 0,04159 | 795,4 | 0,04046 | 794,7 | 0,03940 | 794,1 |
| 480 | 0,04233 | 801,4 | 0,04119 | 800,8 | 0,04010 | 800,2 |
| 490 | 0,04305 | 807,4 | 0,04190 | 806,8 | 0,04080 | 806,2 |
| 500 | 0,04377 | 813,3 | 0,04260 | 812,8 | 0,04149 | 812,2 |
| 510 | 0,04448 | 819,2 | 0,04330 | 818,7 | 0,04217 | 818,2 |
| 520 | 0,04519 | 825,1 | 0,04399 | 824,6 | 0,04285 | 824,1 |
| 530 | 0,01589 | 831,0 | 0,04468 | 830,5 | 0,04353 | 830,0 |
| 540 | 0,04659 | 836,8 | 0,04536 | 836,4 | 0,04419 | 835,9 |
| 550 | 0,04728 | (1) 842,6 | 0,04604 | (1) 842,2 | 0,04485 | (1) 841,8 |

| | *p* = 84 *ama* | | *p* = 86 *ama* | | *p* = 88 *ama* | |
|---|---|---|---|---|---|---|
| 300 | 0,02315 | 661,9 | 0,02230 | 659,0 | | |
| 310 | 0,02452 | 674,3 | 0,02368 | 671,8 | 0,02286 | 669,4 |
| 320 | 0,02574 | 684,9 | 0,02490 | 682,8 | 0,02410 | 680,8 |
| 330 | 0,02685 | 694,5 | 0,02602 | 692,7 | 0,02522 | 690,9 |
| 340 | 0,02789 | 703,4 | 0,02705 | 701,8 | 0,02626 | 700,2 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| 350 | 0,02887 | 711,7 | 0,02802 | 710,3 | 0,02722 | 708,9 |
| 360 | 0,02980 | 719,6 | 0,02895 | 718,3 | 0,02814 | 717,1 |
| 370 | 0,03069 | 727,2 | 0,02983 | 726,0 | 0,02901 | 724,8 |
| 380 | 0,03155 | 734,5 | 0,03068 | 733,4 | 0,02985 | 732,3 |
| 390 | 0,03238 | 741,6 | 0,03150 | 740,6 | 0,03066 | 739,6 |
| 400 | 0,03319 | 748,5 | 0,03230 | 747,5 | 0,03145 | 746,6 |
| 410 | 0,03398 | 755,3 | 0,03307 | 754,3 | 0,03222 | 753,6 |
| 420 | 0,03475 | 761,9 | 0,03382 | 761,0 | 0,03295 | 760,2 |
| 430 | 0,03550 | 768,4 | 0,03457 | 767,6 | 0,03368 | 766,8 |
| 440 | 0,03624 | 774,8 | 0,03530 | 774,0 | 0,03440 | 773,3 |
| 450 | 0,03696 | 781,1 | 0,03601 | 780,3 | 0,03510 | 779,7 |
| 460 | 0,03767 | 787,3 | 0,03671 | 786,6 | 0,03579 | 786,0 |
| 470 | 0,03837 | 793,5 | 0,03740 | 792,8 | 0,03647 | 792,2 |
| 480 | 0,03907 | 799,6 | 0,03808 | 799,0 | 0,03714 | 798,4 |
| 490 | 0,03975 | 805,7 | 0,03875 | 805,1 | 0,03780 | 804,5 |
| 500 | 0,04043 | 811,7 | 0,03942 | 811,1 | 0,03846 | 810,6 |
| 510 | 0,04111 | 817,7 | 0,04008 | 817,1 | 0,03911 | 816,6 |
| 520 | 0,04177 | 823,6 | 0,04073 | 823,1 | 0,03975 | 822,6 |
| 530 | 0,04243 | 829,5 | 0,04138 | 829,1 | 0,04038 | 828,6 |
| 540 | 0,04308 | 835,4 | 0,04202 | 835,0 | 0,04101 | 834,5 |
| 550 | 0,04373 | 841,3 | 0,04265 | 840,9 | 0,04163 | 840,4 |
| | (1) $p = 90$ ama | | (1) $p = 92$ ama | | (1) $p = 94$ ama | |
| 310 | 0,02209 | 666,9 | 0,02132 | 664,2 | 0,02059 | 661,4 |
| 320 | 0,02333 | 678,6 | 0,02253 | 676,4 | 0,02187 | 674,1 |
| 330 | 0,02446 | 689,0 | 0,02371 | 687,1 | 0,02300 | 685,2 |
| 340 | 0,02550 | 698,5 | 0,02474 | 696,8 | 0,02403 | 695,1 |
| 350 | 0,02645 | 707,3 | 0,02570 | 705,8 | 0,02499 | 704,3 |
| 360 | 0,02736 | 715,6 | 0,02661 | 714,1 | 0,02589 | 712,9 |
| 370 | 0,02823 | 723,5 | 0,02747 | 722,2 | 0,02675 | 721,0 |
| 380 | 0,02906 | 731,1 | 0,02830 | 730,0 | 0,02756 | 728,9 |
| 390 | 0,02987 | 738,5 | 0,02909 | 737,5 | 0,02835 | 736,4 |
| 400 | 0,03065 | 745,6 | 0,02986 | 744,6 | 0,02911 | 743,7 |
| 410 | 0,03140 | 752,5 | 0,03060 | 751,6 | 0,02985 | 750,7 |
| 420 | 0,03213 | 759,4 | 0,03133 | 758,4 | 0,03057 | 757,6 |
| 430 | 0,03285 | 766,0 | 0,03204 | 765,1 | 0,03127 | 764,4 |
| 440 | 0,03356 | 772,5 | 0,03273 | 771,7 | 0,03195 | 771,0 |
| 450 | 0,03425 | 778,9 | 0,03341 | 778,2 | 0,03262 | 777,5 |
| 460 | 0,03493 | 785,2 | 0,03408 | 784,6 | 0,03327 | 783,9 |
| 470 | 0,03559 | 791,5 | 0,03474 | 790,9 | 0,03392 | 790,2 |
| 480 | 0,03625 | 797,7 | 0,03539 | 797,1 | 0,03456 | 796,5 |
| 490 | 0,03690 | 803,9 | 0,03603 | 803,3 | 0,03519 | 802,7 |
| 500 | 0,03754 | 810,0 | 0,03665 | 809,5 | 0,03581 | 808,9 |
| 510 | 0,03818 | 816,1 | 0,03728 | 815,6 | 0,03642 | 815,0 |
| 520 | 0,03881 | 822,1 | 0,03790 | 821,6 | 0,03703 | 821,1 |
| 530 | 0,03943 | 828,1 | 0,03851 | 827,6 | 0,03763 | 827,1 |
| 540 | 0,04005 | 834,1 | 0,03911 | 833,6 | 0,03823 | 833,1 |
| 550 | 0,04066 | 840,0 | 0,03971 | 839,5 | 0,03882 | 839,1 |
| | (1) $p = 96$ ama | | (1) $p = 98$ ama | | (1) $p = 100$ ama | |
| 310 | 0,01988 | 658,6 | 0,01919 | 655,6 | 0,01852 | 652,5 |
| 320 | 0,02118 | 671,8 | 0,02051 | 669,4 | 0,01986 | 666,9 |
| 330 | 0,02231 | 683,4 | 0,02165 | 681,2 | 0,02102 | 679,0 |
| 340 | 0,02335 | 693,4 | 0,02269 | 691,6 | 0,02206 | 689,3 |
| 350 | 0,02431 | 702,7 | 0,02365 | 701,2 | 0,02301 | 699,6 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| 360 | 0,02520 | 711,5 | 0,02452 | 710,1 | 0,02390 | 708,6 |
| 370 | 0,02605 | 719,8 | 0,02539 | 718,5 | 0,02475 | 717,1 |
| 380 | 0,02688 | 727,7 | 0,02619 | 726,5 | 0,02555 | 725,3 |
| 390 | 0,02765 | 735,3 | 0,02696 | 734,2 | 0,02631 | 733,1 |
| 400 | 0,02840 | 742,6 | 0,02771 | 741,6 | 0,02705 | 740,6 |
| 410 | 0,02912 | 749,7 | 0,02843 | 748,8 | 0,02776 | 747,9 |
| 420 | 0,02983 | 756,7 | 0,02913 | 755,8 | 0,02845 | 755,0 |
| 430 | 0,03052 | 763,5 | 0,02981 | 762,7 | 0,02913 | 761,9 |
| 440 | 0,03120 | 770,2 | 0,03048 | 769,5 | 0,02979 | 768,7 |
| 450 | 0,03187 | 776,8 | 0,03113 | 776,1 | 0,03043 | 775,4 |
| 460 | 0,03252 | 783,3 | 0,03177 | 782,5 | 0,03106 | 781,9 |
| 470 | 0,03315 | 789,7 | 0,03240 | 788,9 | 0,03168 | 788,3 |
| 480 | 0,03377 | 796,0 | 0,03301 | 795,2 | 0,03228 | 794,7 |
| 490 | 0,03439 | 802,2 | 0,03362 | 801,5 | 0,03288 | 801,0 |
| 500 | 0,03500 | 808,3 | 0,03423 | 807,8 | 0,03348 | 807,2 |
| 510 | 0,03560 | 814,5 | 0,03483 | 814,0 | 0,03407 | 813,4 |
| 520 | 0,03620 | 820,6 | 0,03541 | 820,1 | 0,03464 | 819,6 |
| 530 | 0,03679 | 826,6 | 0,03599 | 826,2 | 0,03521 | 825,7 |
| 540 | 0,03738 | 832,6 | 0,03656 | 832,2 | 0,03578 | 831,7 |
| 550 | 0,03796 | 838,6 | 0,03713 | 838,2 | 0,03634 | 837,7 |
| 560 | — | — | — | — | 0,03689 | 843,7 |
| 570 | — | — | — | — | 0,03744 | 819,7 |
| 580 | — | — | — | — | 0,03799 | 855,7 |
| 590 | — | — | — | — | 0,03853. | 861,6 |
| 600 | — | — | — | — | 0,03907 | 867,5 |
| | $p = 105$ ama | 1 | $p = 110$ ama | 1 | $p = 115$ ama | 1 |
| 320 | 0,01834 | 660,2 | 0,01687 | 653,0 | 0,01549 | 645,0 |
| 330 | 0,01952 | 673,6 | 0,01812 | 667,8 | 0,01680 | 661,5 |
| 340 | 0,02056 | 685,2 | 0,01919 | 680,3 | 0,01792 | 675,0 |
| 350 | 0,02152 | 695,5 | 0,02016 | 691,2 | 0,01890 | 686,7 |
| 360 | 0,02241 | 704,9 | 0,02105 | 701,1 | 0,01979 | 697,2 |
| 370 | 0,02325 | 713,8 | 0,02187 | 710,4 | 0,02061 | 706,9 |
| 380 | 0,02404 | 722,3 | 0,02265 | 719,2 | 0,02138 | 716,0 |
| 390 | 0,02479 | 730,3 | 0,02339 | 727,5 | 0,02211 | 724,6 |
| 400 | 0,02551 | 738,0 | 0,02410 | 735,4 | 0,02281 | 732,8 |
| 410 | 0,02621 | 745,5 | 0,02478 | 743,1 | 0,02348 | 740,7 |
| 420 | 0,02688 | 752,7 | 0,02544 | 750,6 | 0,02412 | 748,3 |
| 430 | 0,02753 | 759,8 | 0,02608 | 757,8 | 0,02475 | 755,6 |
| 440 | 0,02816 | 766,7 | 0,02670 | 764,8 | 0,02536 | 762,8 |
| 450 | 0,02878 | 773,5 | 0,02730 | 771,7 | 0,02595 | 769,8 |
| 460 | 0,02940 | 780,1 | 0,02789 | 778,4 | 0,02652 | 776,6 |
| 470 | 0,03000 | 786,6 | 0,02847 | 785,0 | 0,02708 | 783,3 |
| 480 | 0,03059 | 793,1 | 0,02904 | 791,5 | 0,02763 | 789,9 |
| 490 | 0,03117 | 799,5 | 0,02960 | 798,0 | 0,02817 | 796,5 |
| 500 | 0,03174 | 805,9 | 0,03015 | 804,4 | 0,02871 | 803,0 |
| 510 | 0,03230 | 812,1 | 0,03070 | 810,7 | 0,02924 | 809,4 |
| 520 | 0,03286 | 818,3 | 0,03124 | 817,0 | 0,02976 | 815,7 |
| 530 | 0,03341 | 824,5 | 0,03177 | 823,2 | 0,03027 | 822,0 |
| 540 | 0,03395 | 830,6 | 0,03229 | 829,4 | 0,03078 | 828,2 |
| 550 | 0,03449 | 836,7 | 0,03281 | 835,5 | 0,03128 | 834,4 |
| 560 | 0,03502 | 842,7 | 0,03332 | 841,6 | 0,03177 | 840,5 |
| 570 | 0,03555 | 848,7 | 0,03383 | 847,7 | 0,03226 | 846,6 |
| 580 | 0,03608 | 854,7 | 0,03434 | 853,8 | 0,03275 | 852,7 |
| 590 | 0,03660 | 860,7 | 0,03484 | 859,8 | 0,03323 | 858,7 |
| 600 | 0,03711 | 856,6 | 0,03533 | 865,8 | 0,03371 | 864,7 |

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| | $p$ = 120 ama (1) | | $p$ = 125 ama (1) | | $p$ = 130 ama (1) | |
|---|---|---|---|---|---|---|
| 330 | 0,01557 | 654,6 | 0,01439 | 646,9 | 0,01326 | 638,5 |
| 340 | 0,01674 | 669,4 | 0,01563 | 663,4 | 0,01453 | 656,9 |
| 350 | 0,01772 | 682,0 | 0,01664 | 677,0 | 0,01560 | 671,7 |
| 360 | 0,01862 | 693,1 | 0,01754 | 688,8 | 0,01653 | 684,3 |
| 370 | 0,01945 | 703,3 | 0,01837 | 699,5 | 0,01736 | 695,6 |
| 380 | 0,02022 | 712,7 | 0,01914 | 709,4 | 0,01813 | 705,9 |
| 390 | 0,02094 | 721,6 | 0,01986 | 718,6 | 0,01885 | 715,4 |
| 400 | 0,02163 | 730,0 | 0,02054 | 727,2 | 0,01952 | 724,4 |
| 410 | 0,02229 | 738,1 | 0,02119 | 735,9 | 0,02016 | 732,9 |
| 420 | 0,02292 | 745,9 | 0,02181 | 743,5 | 0,02077 | 741,1 |
| 430 | 0,02353 | 753,4 | 0,02240 | 751,2 | 0,02136 | 749,0 |
| 440 | 0,02412 | 760,7 | 0,02297 | 758,7 | 0,02193 | 756,6 |
| 450 | 0,02469 | 767,8 | 0,02353 | 765,9 | 0,02248 | 763,9 |
| 460 | 0,02525 | 774,8 | 0,02408 | 773,0 | 0,02301 | 771,1 |
| 470 | 0,02580 | 781,7 | 0,02462 | 779,9 | 0,02353 | 778,2 |
| 480 | 0,02634 | 788,4 | 0,02515 | 786,7 | 0,02404 | 785,1 |
| 490 | 0,02687 | 795,0 | 0,02567 | 793,4 | 0,02455 | 791,9 |
| 500 | 0,02739 | 801,5 | 0,02617 | 800,0 | 0,02504 | 798,6 |
| 510 | 0,02790 | 808,0 | 0,02666 | 806,6 | 0,02552 | 805,2 |
| 520 | 0,02840 | 814,4 | 0,02715 | 813,1 | 0,02599 | 811,7 |
| 530 | 0,02890 | 820,7 | 0,02763 | 819,5 | 0,02646 | 818,2 |
| 540 | 0,02939 | 827,0 | 0,02811 | 825,8 | 0,02692 | 824,6 |
| 550 | 0,02987 | 833,2 | 0,02858 | 832,1 | 0,02738 | 830,9 |
| 560 | 0,03035 | 839,4 | 0,02904 | 838,3 | 0,02783 | 837,2 |
| 570 | 0,03082 | 845,5 | 0,02950 | 844,5 | 0,02827 | 843,4 |
| 580 | 0,03129 | 851,6 | 0,02995 | 850,7 | 0,02871 | 849,6 |
| 590 | 0,03176 | 857,7 | 0,03040 | 856,8 | 0,02915 | 855,8 |
| 600 | 0,03222 | 863,8 | 0,03085 | 862,9 | 0,02958 | 861,9 |

| | $p$ = 135 ama (1) | | $p$ = 140 ama (1) | | $p$ = 145 ama (1) | |
|---|---|---|---|---|---|---|
| 340 | 0,01352 | 649,9 | 0,01254 | 642,2 | 0,01158 | 633,6 |
| 350 | 0,01464 | 666,1 | 0,01373 | 660,1 | 0,01284 | 653,6 |
| 360 | 0,01558 | 679,6 | 0,01469 | 674,7 | 0,01386 | 669,5 |
| 370 | 0,01642 | 691,5 | 0,01554 | 687,3 | 0,01474 | 682,9 |
| 380 | 0,01720 | 702,3 | 0,01631 | 698,6 | 0,01552 | 694,8 |
| 390 | 0,01792 | 712,2 | 0,01702 | 708,9 | 0,01623 | 705,5 |
| 400 | 0,01858 | 721,5 | 0,01769 | 718,5 | 0,01689 | 715,5 |
| 410 | 0,01921 | 730,3 | 0,01832 | 727,6 | 0,01751 | 724,9 |
| 420 | 0,01981 | 738,7 | 0,01892 | 736,2 | 0,01810 | 733,7 |
| 430 | 0,02039 | 746,7 | 0,01949 | 744,4 | 0,01866 | 742,1 |
| 440 | 0,02095 | 754,4 | 0,02004 | 752,3 | 0,01920 | 750,2 |
| 450 | 0,02149 | 761,9 | 0,02057 | 759,9 | 0,01972 | 758,0 |
| 460 | 0,02202 | 769,3 | 0,02109 | 767,4 | 0,02022 | 765,5 |
| 470 | 0,02253 | 776,5 | 0,02159 | 774,7 | 0,02071 | 772,9 |
| 480 | 0,02303 | 783,5 | 0,02208 | 781,8 | 0,02119 | 780,2 |
| 490 | 0,02351 | 790,4 | 0,02255 | 788,8 | 0,02166 | 787,3 |
| 500 | 0,02399 | 797,1 | 0,02302 | 795,6 | 0,02212 | 794,2 |
| 510 | 0,02446 | 803,8 | 0,02348 | 802,3 | 0,02257 | 801,0 |
| 520 | 0,02492 | 810,4 | 0,02393 | 809,0 | 0,02301 | 807,7 |
| 530 | 0,02538 | 816,9 | 0,02437 | 815,6 | 0,02344 | 814,3 |

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|---|---|---|---|---|---|---|
| 540 | 0,02583 | 823,4 | 0,02481 | 822,1 | 0,02387 | 820,9 |
| 550 | 0,02627 | 829,8 | 0,02524 | 828,5 | 0,02429 | 827,4 |
| 560 | 0,02671 | 836,1 | 0,02567 | 834,9 | 0,02470 | 833,8 |
| 570 | 0,02714 | 842,4 | 0,02609 | 841,3 | 0,02511 | 840,2 |
| 580 | 0,02757 | 848,6 | 0,02650 | 847,6 | 0,02551 | 846,6 |
| 590 | 0,02799 | 854,8 | 0,02691 | 853,8 | 0,02591 | 852,9 |
| 600 | 0,02841 | 861,0 | 0,02732 | 860,0 | 0,02631 | 859,1 |
| | $p = 150$ *ama* 1 | | $p = 155$ *ama* 1 | | $p = 160$ *ama* 1 | |
| 350 | 0,01198 | 646,8 | 0,01114 | 639,5 | 0,01033 | 630,9 |
| 360 | 0,01307 | 664,1 | 0,01230 | 658,4 | 0,01151 | 652,2 |
| 370 | 0,01396 | 678,4 | 0,01321 | 673,9 | 0,01247 | 668,9 |
| 380 | 0,01475 | 691,0 | 0,01401 | 687,0 | 0,01330 | 682,8 |
| 390 | 0,01546 | 702,2 | 0,01473 | 698,7 | 0,01403 | 695,0 |
| 400 | 0,01611 | 712,4 | 0,01539 | 709,3 | 0,01469 | 706,0 |
| 410 | 0,01672 | 722,0 | 0,01600 | 719,2 | 0,01531 | 716,2 |
| 420 | 0,01730 | 731,1 | 0,01658 | 728,5 | 0,01589 | 725,8 |
| 430 | 0,01786 | 739,7 | 0,01713 | 737,3 | 0,01643 | 734,9 |
| 440 | 0,01840 | 747,9 | 0,01766 | 745,7 | 0,01695 | 743,5 |
| 450 | 0,01892 | 755,9 | 0,01817 | 753,8 | 0,01746 | 751,7 |
| 460 | 0,01942 | 763,6 | 0,01866 | 761,7 | 0,01795 | 759,7 |
| 470 | 0,01990 | 771,1 | 0,01913 | 769,4 | 0,01842 | 767,5 |
| 480 | 0,02037 | 778,4 | 0,01959 | 776,8 | 0,01887 | 775,0 |
| 490 | 0,02083 | 785,6 | 0,02004 | 784,0 | 0,01931 | 782,3 |
| 500 | 0,02127 | 792,6 | 0,02048 | 791,1 | 0,01974 | 789,6 |
| 510 | 0,02171 | 799,5 | 0,02091 | 798,1 | 0,02016 | 796,7 |
| 520 | 0,02214 | 806,3 | 0,02133 | 805,0 | 0,02057 | 803,6 |
| 530 | 0,02257 | 813,0 | 0,02174 | 811,8 | 0,02098 | 810,4 |
| 540 | 0,02298 | 819,6 | 0,02215 | 818,5 | 0,02138 | 817,2 |
| 550 | 0,02339 | 826,2 | 0,02255 | 825,1 | 0,02177 | 823,9 |
| 560 | 0,02379 | 832,7 | 0,02295 | 831,6 | 0,02215 | 830,5 |
| 570 | 0,02419 | 839,1 | 0,02334 | 838,1 | 0,02253 | 837,0 |
| 580 | 0,02459 | 845,5 | 0,02372 | 844,5 | 0,02291 | 843,5 |
| 590 | 0,02498 | 851,9 | 0,02410 | 850,9 | 0,02328 | 849,9 |
| 600 | 0,02536 | 858,2 | 0,02448 | 857,2 | 0,02365 | 856,2 |
| 610 | 0,02574 | 864,4 | 0,02485 | 863,6 | 0,02401 | 862,6 |
| 620 | 0,02612 | 870,7 | 0,02522 | 869,8 | 0,02436 | 868,9 |
| 630 | 0,02649 | 876,8 | 0,02559 | 876,0 | 0,02472 | 875,1 |
| 640 | 0,02686 | 883,0 | 0,02594 | 882,2 | 0,02507 | 881,3 |
| 650 | 0,02723 | 889,1 | 0,02630 | 888,3 | 0,02542 | 887,5 |
| | $p = 165$ *ama* 1 | | $p = 170$ *ama* 1 | | $p = 175$ *ama* 1 | |
| 350 | 0,00953 | 620,7 | | | | |
| 360 | 0,01081 | 645,5 | 0,01011 | 638,0 | 0,00939 | 629,4 |
| 370 | 0,01182 | 663,5 | 0,01116 | 657,7 | 0,01052 | 651,6 |
| 380 | 0,01267 | 678,3 | 0,01203 | 673,6 | 0,01143 | 668,8 |
| 390 | 0,01341 | 691,2 | 0,01278 | 687,1 | 0,01219 | 683,1 |
| 400 | 0,01407 | 702,7 | 0,01345 | 699,2 | 0,01286 | 695,6 |
| 410 | 0,01468 | 713,2 | 0,01406 | 710,0 | 0,01348 | 706,9 |
| 420 | 0,01525 | 723,1 | 0,01463 | 720,2 | 0,01406 | 717,4 |
| 430 | 0,01579 | 732,4 | 0,01517 | 729,8 | 0,01460 | 727,2 |
| 440 | 0,01630 | 741,2 | 0,01569 | 738,9 | 0,01510 | 736,5 |

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|---|---|---|---|---|---|---|
| 450 | 0,01680 | 749,7 | 0,01618 | 747,5 | 0,01558 | 745,3 |
| 460 | 0,01728 | 757,8 | 0,01665 | 755,8 | 0,01606 | 753,7 |
| 470 | 0,01774 | 765,6 | 0,01710 | 763,8 | 0,01650 | 761,8 |
| 480 | 0,01819 | 773,2 | 0,01754 | 771,5 | 0,01694 | 769,7 |
| 490 | 0,01862 | 780,7 | 0,01797 | 779,0 | 0,01736 | 777,4 |
| 500 | 0,01904 | 788,0 | 0,01839 | 786,4 | 0,01777 | 784,9 |
| 510 | 0,01945 | 795,2 | 0,01879 | 793,7 | 0,01817 | 792,2 |
| 520 | 0,01986 | 802,2 | 0,01919 | 800,8 | 0,01856 | 799,4 |
| 530 | 0,02026 | 809,1 | 0,01958 | 807,8 | 0,01894 | 806,5 |
| 540 | 0,02065 | 815,9 | 0,01996 | 814,7 | 0,01931 | 813,5 |
| 550 | 0,02103 | 822,6 | 0,02034 | 821,5 | 0,01968 | 820,3 |
| 560 | 0,02141 | 829,3 | 0,02071 | 828,2 | 0,02004 | 827,0 |
| 570 | 0,02178 | 835,9 | 0,02107 | 834,8 | 0,02040 | 833,7 |
| 580 | 0,02215 | 842,4 | 0,02143 | 841,4 | 0,02075 | 840,3 |
| 590 | 0,02251 | 848,9 | 0,02178 | 847,9 | 0,02110 | 846,9 |
| 600 | 0,02287 | 855,3 | 0,02213 | 854,3 | 0,02144 | 853,4 |
| 610 | 0,02322 | 861,7 | 0,02248 | 860,8 | 0,02178 | 859,9 |
| 620 | 0,02357 | 868,0 | 0,02282 | 867,1 | 0,02211 | 866,2 |
| 630 | 0,02392 | 874,3 | 0,02315 | 873,4 | 0,02244 | 872,6 |
| 640 | 0,02426 | 880,5 | 0,02349 | 879,7 | 0,02277 | 878,9 |
| 650 | 0,02460 | 886,8 | 0,02382 | 886,0 | 0,02309 | 885,2 |
| | $p$ = 180 ama (1) | | $p$ = 185 ama (1) | | $p$ = 190 ama (1) | |
| 360 | 0,00866 | 619,7 | 0,00789 | 608,5 | 0,00702 | 593,8 |
| 370 | 0,00990 | 645,0 | 0,00929 | 637,8 | 0,00868 | 629,9 |
| 380 | 0,01085 | 663,6 | 0,01029 | 658,1 | 0,00974 | 652,4 |
| 390 | 0,01162 | 678,7 | 0,01107 | 674,1 | 0,01055 | 669,5 |
| 400 | 0,01230 | 691,8 | 0,01177 | 687,8 | 0,01126 | 683,9 |
| 410 | 0,01292 | 703,5 | 0,01240 | 700,1 | 0,01189 | 696,6 |
| 420 | 0,01350 | 714,3 | 0,01297 | 711,3 | 0,01247 | 708,2 |
| 430 | 0,01404 | 724,5 | 0,01351 | 721,7 | 0,01301 | 718,9 |
| 440 | 0,01455 | 734,1 | 0,01402 | 731,5 | 0,01352 | 728,9 |
| 450 | 0,01503 | 743,1 | 0,01450 | 740,8 | 0,01400 | 738,4 |
| 460 | 0,01549 | 751,7 | 0,01496 | 749,6 | 0,01445 | 747,4 |
| 470 | 0,01593 | 759,9 | 0,01539 | 758,0 | 0,01488 | 756,0 |
| 480 | 0,01636 | 767,9 | 0,01581 | 766,1 | 0,01530 | 764,3 |
| 490 | 0,01678 | 775,7 | 0,01622 | 774,0 | 0,01571 | 772,3 |
| 500 | 0,01718 | 783,3 | 0,01662 | 781,7 | 0,01610 | 780,1 |
| 510 | 0,01757 | 790,7 | 0,01701 | 789,2 | 0,01648 | 787,7 |
| 520 | 0,01795 | 798,0 | 0,01738 | 796,5 | 0,01685 | 795,1 |
| 530 | 0,01833 | 805,1 | 0,01775 | 803,7 | 0,01722 | 802,4 |
| 540 | 0,01870 | 812,1 | 0,01812 | 810,8 | 0,01758 | 809,6 |
| 550 | 0,01906 | 819,0 | 0,01848 | 817,8 | 0,01793 | 816,7 |
| 560 | 0,01942 | 825,8 | 0,01883 | 824,7 | 0,01827 | 823,6 |
| 570 | 0,01977 | 832,6 | 0,01917 | 831,5 | 0,01860 | 830,4 |
| 580 | 0,02011 | 839,3 | 0,01951 | 838,2 | 0,01893 | 837,1 |
| 590 | 0,02045 | 845,9 | 0,01984 | 844,8 | 0,01926 | 843,8 |
| 600 | 0,02079 | 852,4 | 0,02017 | 851,4 | 0,01959 | 850,4 |
| 610 | 0,02112 | 858,9 | 0,02049 | 858,0 | 0,01990 | 857,1 |
| 620 | 0,02145 | 865,3 | 0,02081 | 864,5 | 0,02021 | 863,6 |
| 630 | 0,02177 | 871,7 | 0,02113 | 870,9 | 0,02052 | 870,0 |
| 640 | 0,02209 | 878,1 | 0,02145 | 877,2 | 0,02083 | 876,4 |
| 650 | 0,02240 | 884,4 | 0,02176 | 883,6 | 0,02114 | 882,8 |

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cont.

| | | | | | | |
|---|---|---|---|---|---|---|
| | p = 195 ama (1) | | p = 200 ama (1) | | p = 210 ama (1) | |
| 370 | 0,00807 | 621,0 | 0,00746 | 610,9 | 0,00597 | 582,6 |
| 380 | 0,00921 | 646,1 | 0,00870 | 639,6 | 0,00766 | 624,9 |
| 390 | 0,01005 | 664,6 | 0,00957 | 659,4 | 0,00866 | 648,4 |
| 400 | 0,01078 | 679,9 | 0,01031 | 675,4 | 0,00941 | 666,5 |
| 410 | 0,01142 | 693,1 | 0,01095 | 689,4 | 0,01008 | 681,8 |
| 420 | 0,01200 | 705,0 | 0,01153 | 701,8 | 0,01068 | 695,1 |
| 430 | 0,01254 | 716,0 | 0,01207 | 713,1 | 0,01122 | 707,1 |
| 440 | 0,01304 | 726,3 | 0,01258 | 723,7 | 0,01172 | 718,3 |
| 450 | 0,01352 | 736,0 | 0,01305 | 733,6 | 0,01219 | 728,7 |
| 460 | 0,01397 | 745,2 | 0,01350 | 742,9 | 0,01264 | 738,4 |
| 470 | 0,01440 | 753,9 | 0,01393 | 751,8 | 0,01307 | 747,6 |
| 480 | 0,01481 | 762,3 | 0,01434 | 760,4 | 0,01348 | 756,5 |
| 490 | 0,01521 | 770,5 | 0,01474 | 768,7 | 0,01387 | 765,1 |
| 500 | 0,01560 | 778,5 | 0,01513 | 776,8 | 0,01424 | 773,4 |
| 510 | 0,01598 | 786,2 | 0,01550 | 784,6 | 0,01460 | 781,4 |
| 520 | 0,01635 | 793,7 | 0,01586 | 792,2 | 0,01495 | 789,2 |
| 530 | 0,01671 | 801,0 | 0,01621 | 799,6 | 0,01530 | 796,8 |
| 540 | 0,01706 | 808,3 | 0,01656 | 806,9 | 0,01564 | 804,3 |
| 550 | 0,01740 | 815,4 | 0,01690 | 814,0 | 0,01597 | 811,6 |
| 560 | 0,01773 | 822,4 | 0,01723 | 821,1 | 0,01629 | 818,8 |
| 570 | 0,01806 | 829,3 | 0,01755 | 828,1 | 0,01660 | 825,8 |
| 580 | 0,01839 | 836,1 | 0,01787 | 835,0 | 0,01691 | 832,8 |
| 590 | 0,01871 | 842,8 | 0,01819 | 841,8 | 0,01722 | 839,7 |
| 600 | 0,01903 | 849,5 | 0,01850 | 848,5 | 0,01752 | 846,5 |
| 610 | 0,01934 | 856,1 | 0,01880 | 855,2 | 0,01781 | 853,3 |
| 620 | 0,01965 | 862,7 | 0,01910 | 861,7 | 0,01810 | 859,9 |
| 630 | 0,01995 | 869,2 | 0,01940 | 868,3 | 0,01839 | 866,5 |
| 640 | 0,02025 | 875,6 | 0,01970 | 874,8 | 0,01868 | 873,1 |
| 650 | 0,02055 | 882,0 | 0,02000 | 381,2 | 0,01896 | 879,6 |

*Продолжение*

| t, °C | v, m³/kg | i, kcal/kg | t, °C | v, м³/кг | i, kcal/kg | t, °C | v, m³/kg | i, kcal/kg |
|---|---|---|---|---|---|---|---|---|
| | p = 220 ama (1) | | | p = 220 ama (1) | | | p = 220 ama (1) | |
| 380 | 0,00661 | 606,3 | 510 | 0,01379 | 778,3 | 640 | 0,01775 | 871,4 |
| 390 | 0,00778 | 636,0 | 520 | 0,01413 | 786,2 | 650 | 0,01802 | 878,0 |
| 400 | 0,00857 | 657,1 | 530 | 0,01447 | 794,0 | 660 | 0,01829 | 884,5 |
| 410 | 0,00927 | 673,9 | 540 | 0,01480 | 801,6 | 670 | 0,01855 | 890,9 |
| 420 | 0,00988 | 688,2 | 550 | 0,01512 | 809,0 | 680 | 0,01881 | 897,4 |
| 430 | 0,01043 | 701,0 | 560 | 0,01543 | 816,3 | 690 | 0,01907 | 903,8 |
| 440 | 0,01094 | 712,8 | 570 | 0,01574 | 823,5 | 700 | 0,01933 | 910,2 |
| 450 | 0,01141 | 723,7 | 580 | 0,01604 | 830,6 | 710 | 0,01959 | 916,6 |
| 460 | 0,01185 | 733,8 | 590 | 0,01634 | 837,6 | 720 | 0,01985 | 922,8 |
| 470 | 0,01227 | 743 [illegible] | 600 | 0,01663 | 844,5 | 730 | 0,02010 | 929,2 |
| 480 | 0,01268 | 75[illegible],6 | 610 | 0,01692 | 851,4 | 740 | 0,02035 | 935,4 |
| 490 | 0,01307 | 761,5 | 620 | 0,01719 | 858,1 | 750 | 0,02060 | 941,6 |
| 500 | 0,01344 | 770,1 | 630 | 0,01747 | 864,8 | | | |

Key: (1). atm(abs).

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| t, °C | v, м³/кг (1) | i, ккал/кг (2) | v, м³/кг (1) | i, ккал/кг (2) | v, м³/кг (1) | i, ккал/кг (2) |
|---|---|---|---|---|---|---|
| | p = 230 ата (3) | | p = 240 ата (3) | | p = 250 ата (3) | |
| 0 | 0,0009891 | 5,4 | 0,0009887 | 5,7 | 0,0009882 | 5,9 |
| 10 | 0,0009901 | 15,2 | 0,0009897 | 15,5 | 0,0009892 | 15,7 |
| 20 | 0,0009920 | 25,1 | 0,0009916 | 25,3 | 0,0009912 | 25,5 |
| 30 | 0,0009947 | 34,9 | 0,0009944 | 35,1 | 0,0009940 | 35,3 |
| 40 | 0,0009982 | 44,7 | 0,0009978 | 44,9 | 0,0009974 | 45,1 |
| 50 | 0,0010023 | 54,6 | 0,0010019 | 54,8 | 0,0010015 | 55,0 |
| 60 | 0,0010071 | 64,4 | 0,0010067 | 64,6 | 0,0010062 | 64,8 |
| 70 | 0,0010125 | 74,3 | 0,0010121 | 75,5 | 0,0010116 | 74,7 |
| 80 | 0,0010185 | 84,2 | 0,0010181 | 84,4 | 0,0010176 | 84,6 |
| 90 | 0,0010251 | 94,2 | 0,0010247 | 94,4 | 0,0010242 | 94,6 |
| 100 | 0,0010323 | 104,2 | 0,0010318 | 104,4 | 0,0010314 | 104,6 |
| 110 | 0,0010400 | 114,2 | 0,0010395 | 114,4 | 0,0010391 | 114,5 |
| 120 | 0,0010483 | 124,2 | 0,0010478 | 124,4 | 0,0010473 | 124,5 |
| 130 | 0,0010572 | 134,2 | 0,0010567 | 134,4 | 0,0010561 | 134,5 |
| 140 | 0,0010666 | 144,3 | 0,0010661 | 144,4 | 0,0010655 | 144,6 |
| 150 | 0,0010766 | 154,4 | 0,0010760 | 154,5 | 0,0010754 | 154,7 |
| 160 | 0,0010873 | 164,5 | 0,0010860 | 164,6 | 0,0010860 | 164,8 |
| 170 | 0,0010986 | 174,7 | 0,0010979 | 174,8 | 0,0010972 | 174,9 |
| 180 | 0,0011106 | 184,9 | 0,0011099 | 185,0 | 0,0011092 | 185,0 |
| 190 | 0,0011234 | 195,2 | 0,0011226 | 195,3 | 0,0011219 | 195,5 |
| 200 | 0,0011370 | 205,6 | 0,0011362 | 205,7 | 0,0011354 | 205,8 |
| 210 | 0,0011515 | 216,1 | 0,0011506 | 216,2 | 0,0011497 | 216,3 |
| 220 | 0,0011670 | 226,7 | 0,0011660 | 226,8 | 0,0011650 | 226,9 |
| 230 | 0,0011835 | 237,5 | 0,0011825 | 237,6 | 0,0011814 | 237,6 |
| 240 | 0,0012015 | 248,4 | 0,0012004 | 248,5 | 0,0011992 | 248,5 |
| 250 | 0,0012210 | 259,5 | 0,0012197 | 259,6 | 0,0012183 | 259,6 |
| 260 | 0,0012422 | 270,8 | 0,0012407 | 270,8 | 0,0012391 | 270,8 |
| 270 | 0,0012655 | 282,2 | 0,0012637 | 282,2 | 0,0012619 | 282,2 |
| 280 | 0,0012911 | 293,9 | 0,0012890 | 293,9 | 0,0012869 | 293,8 |
| 290 | 0,0013195 | 305,8 | 0,0013171 | 305,8 | 0,0013147 | 305,7 |
| 300 | 0,0013517 | 318,1 | 0,0013488 | 318,0 | 0,0013460 | 317,9 |
| 310 | 0,001389 | 330,8 | 0,001385 | 330,7 | 0,001382 | 330,5 |
| 320 | 0,001432 | 344,2 | 0,001427 | 343,9 | 0,001423 | 343,6 |
| 330 | 0,001483 | 358,1 | 0,001477 | 357,7 | 0,001471 | 357,3 |
| 340 | 0,001544 | 373,1 | 0,001536 | 372,5 | 0,001528 | 371,9 |
| 350 | 0,001623 | 389,7 | 0,001611 | 388,7 | 0,001600 | 387,8 |
| 360 | 0,001730 | 408,8 | 0,001709 | 407,1 | 0,001690 | 405,6 |
| 370 | 0,001976 | 436,6 | 0,001904 | 432,1 | 0,001858 | 428,4 |
| 380 | 0,00545 | 580,0 | 0,00366 | 530,2 | 0,00238 | 470,1 |
| 390 | 0,00690 | 621,7 | 0,00601 | 605,8 | 0,00512 | 584,2 |
| 400 | 0,00780 | 646,8 | 0,00707 | 635,5 | 0,00635 | 622,8 |
| 410 | 0,00852 | 665,6 | 0,00782 | 656,6 | 0,00716 | 646,9 |
| 420 | 0,00914 | 681,0 | 0,00846 | 673,5 | 0,00782 | 665,7 |
| 430 | 0,00970 | 694,7 | 0,00903 | 688,2 | 0,00841 | 681,4 |
| 440 | 0,01022 | 707,1 | 0,00955 | 701,3 | 0,00895 | 695,3 |
| 450 | 0,01070 | 718,4 | 0,01004 | 713,2 | 0,00944 | 707,9 |
| 460 | 0,01114 | 729,0 | 0,01048 | 724,3 | 0,00988 | 719,5 |
| 470 | 0,01155 | 739,0 | 0,01089 | 734,7 | 0,01028 | 730,3 |
| 480 | 0,01194 | 748,6 | 0,01128 | 744,6 | 0,01066 | 740,5 |
| 490 | 0,01233 | 757,8 | 0,01166 | 754,0 | 0,01103 | 750,2 |
| 500 | 0,01270 | 766,6 | 0,01202 | 763,0 | 0,01139 | 759,5 |
| 510 | 0,01305 | 775,0 | 0,01237 | 771,7 | 0,01173 | 768,4 |
| 520 | 0,01339 | 783,2 | 0,01270 | 780,1 | 0,01206 | 777,0 |
| 530 | 0,01372 | 791,2 | 0,01302 | 788,2 | 0,01238 | 785,3 |
| 540 | 0,01404 | 799,0 | 0,01333 | 796,1 | 0,01269 | 793,4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 550 | 0,01435 | 806,5 | 0,01364 | 803,8 | 0,01299 | 801,3 |
| 560 | 0,01465 | 813,9 | 0,01394 | 811,4 | 0,01328 | 809,0 |
| 570 | 0,01495 | 821,2 | 0,01423 | 818,9 | 0,01356 | 816,5 |
| 580 | 0,01524 | 828,4 | 0,01451 | 826,2 | 0,01384 | 823,9 |
| 590 | 0,01553 | 835,5 | 0,01479 | 833,4 | 0,01411 | 831,2 |
| 600 | 0,01581 | 842,5 | 0,01507 | 840,4 | 0,01438 | 838,4 |
| 610 | 0,01609 | 849,5 | 0,01533 | 847,6 | 0,01464 | 845,6 |
| 620 | 0,01636 | 856,3 | 0,01560 | 854,4 | 0,01490 | 852,8 |
| 630 | 0,01663 | 863,0 | 0,01587 | 861,3 | 0,01515 | 859,5 |
| 640 | 0,01690 | 869,7 | 0,01613 | 868,0 | 0,01540 | 866,3 |
| 650 | 0,01716 | 876,3 | 0,01638 | 874,7 | 0,01565 | 873,1 |
| 660 | 0,01742 | 882,9 | 0,01663 | 881,4 | 0,01589 | 879,8 |
| 670 | 0,01768 | 889,4 | 0,01687 | 887,9 | 0,01613 | 886,4 |
| 680 | 0,01793 | 895,9 | 0,01712 | 894,5 | 0,01637 | 893,0 |
| 690 | 0,01818 | 902,4 | 0,01736 | 900,9 | 0,01661 | 899,6 |
| 700 | 0,01843 | 908,8 | 0,01760 | 907,5 | 0,01685 | 906,1 |
| 710 | 0,01868 | 915,2 | 0,01784 | 913,9 | 0,01708 | 912,6 |
| 720 | 0,01893 | 921,6 | 0,01808 | 920,3 | 0,01731 | 919,0 |
| 730 | 0,01917 | 927,9 | 0,01832 | 926,7 | 0,01754 | 925,5 |
| 740 | 0,01941 | 934,2 | 0,01855 | 933,0 | 0,01776 | 931,9 |
| 750 | 0,01965 | 940,5 | 0,01878 | 939,3 | 0,01793 | 938,2 |
| | $p = 260$ ата 3 | | $p = 270$ ата 3 | | $p = 280$ ата 3 | |
| 0 | 0,0009877 | 6,1 | 0,0009878 | 6,4 | 0,0009868 | 6,6 |
| 10 | 0,0009888 | 15,9 | 0,0009884 | 16,1 | 0,0009880 | 16,4 |
| 20 | 0,0009908 | 25,7 | 0,0009904 | 25,9 | 0,0009900 | 26,2 |
| 30 | 0,0009936 | 35,5 | 0,0009932 | 35,7 | 0,0009928 | 36,0 |
| 40 | 0,0009970 | 45,3 | 0,0009966 | 45,5 | 0,0009962 | 45,8 |
| 50 | 0,0010011 | 55,2 | 0,0010007 | 55,4 | 0,0010003 | 55,6 |
| 60 | 0,0010058 | 65,0 | 0,0010054 | 65,2 | 0,0010050 | 65,4 |
| 70 | 0,0010112 | 74,9 | 0,0010108 | 75,1 | 0,0010104 | 75,3 |
| 80 | 0,0010172 | 84,8 | 0,0010168 | 85,0 | 0,0010164 | 85,2 |
| 90 | 0,0010238 | 94,8 | 0,0010234 | 95,0 | 0,0010229 | 95,2 |
| 100 | 0,0010309 | 104,7 | 0,0010305 | 104,9 | 0,0010300 | 105,1 |
| 110 | 0,0010386 | 114,7 | 0,0010381 | 114,9 | 0,0010376 | 115,1 |
| 120 | 0,0010[illegible]8 | 124,7 | 0,0010463 | 124,9 | 0,0010458 | 125,0 |
| 130 | 0,0010556 | 134,7 | 0,0010551 | 134,8 | 0,0010546 | 135,0 |
| 140 | 0,0010649 | 144,7 | 0,0010644 | 144,9 | 0,0010639 | 145,0 |
| 150 | 0,0010749 | 154,8 | 0,0010743 | 155,0 | 0,0010737 | 155,1 |
| 160 | 0,0010854 | 164,9 | 0,0010848 | 165,1 | 0,0010842 | 165,2 |
| 170 | 0,0010966 | 175,1 | 0,0010959 | 175,2 | 0,0010953 | 175,4 |
| 180 | 0,0011085 | 185,3 | 0,0011078 | 185,4 | 0,0011071 | 185,6 |
| 190 | 0,0011211 | 195,6 | 0,0011204 | 195,7 | 0,0011196 | 195,8 |
| 200 | 0,0011345 | 205,9 | 0,0011337 | 206,0 | 0,0011328 | 206,1 |
| 210 | 0,0011488 | 216,4 | 0,0011479 | 216,4 | 0,0011470 | 216,6 |
| 220 | 0,0011640 | 227,0 | 0,0011631 | 227,0 | 0,0011621 | 227,1 |
| 230 | 0,0011803 | 237,7 | 0,0011792 | 237,8 | 0,0011781 | 237,8 |
| 240 | 0,0011979 | 248,6 | 0,0011967 | 248,6 | 0,0011955 | 248,7 |
| 250 | 0,0012169 | 259,6 | 0,0012156 | 259,6 | 0,0012143 | 259,7 |
| 260 | 0,0012375 | 270,8 | 0,0012360 | 270,8 | 0,0012346 | 270,8 |
| 270 | 0,0012601 | 282,2 | 0,0012583 | 282,2 | 0,0012567 | 282,1 |
| 280 | 0,0012849 | 293,8 | 0,0012829 | 293,8 | 0,0012810 | 293,7 |
| 290 | 0,0013124 | 305,6 | 0,0013101 | 305,6 | 0,0013079 | 305,5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 300 | 0,0013432 | 317,8 | 0,0013406 | 317,7 | 0,0013379 | 317,5 |
| 310 | 0,001378 | 330,3 | 0,001375 | 330,1 | 0,001372 | 329,9 |
| 320 | 0,001418 | 343,3 | 0,001414 | 343,0 | 0,001410 | 342,7 |
| 330 | 0,001466 | 356,9 | 0,001460 | 356,5 | 0,001455 | 355,9 |
| 340 | 0,001521 | 371,4 | 0,001514 | 370,9 | 0,001508 | 370,4 |
| 350 | 0,001590 | 387,1 | 0,001581 | 386,3 | 0,001577 | 385,6 |
| 360 | 0,001675 | 404,3 | 0,001660 | 403,1 | 0,001659 | 402,0 |
| 370 | 0,001824 | 425,4 | 0,001795 | 423,0 | 0,001780 | 421,1 |
| 380 | 0,00217 | 458,3 | 0,00206 | 451,1 | 0,00199 | 446,2 |
| 390 | 0,00419 | 556,7 | 0,00320 | 521,0 | 0,00257 | 491,4 |
| 400 | 0,00563 | 607,9 | 0,00493 | 590,7 | 0,00425 | 570,1 |
| 410 | 0,00653 | 636,4 | 0,00596 | 624,7 | 0,00539 | 611,6 |
| 420 | 0,00724 | 657,4 | 0,00671 | 648,2 | 0,00618 | 638,2 |
| 430 | 0,00785 | 674,2 | 0,00732 | 666,7 | 0,00683 | 658,7 |
| 440 | 0,00839 | 689,0 | 0,00786 | 682,5 | 0,00737 | 675,8 |
| 450 | 0,00888 | 702,3 | 0,00835 | 696,5 | 0,00787 | 690,7 |
| 460 | 0,00932 | 714,4 | 0,00879 | 709,2 | 0,00831 | 704,0 |
| 470 | 0,00972 | 725,7 | 0,00919 | 721,0 | 0,00872 | 716,4 |
| 480 | 0,01010 | 736,3 | 0,00957 | 732,0 | 0,00911 | 727,7 |
| 490 | 0,01047 | 746,3 | 0,00993 | 742,3 | 0,00947 | 738,4 |
| 500 | 0,01082 | 755,9 | 0,01028 | 752,1 | 0,00980 | 748,5 |
| 510 | 0,01115 | 765,0 | 0,01061 | 761,5 | 0,01012 | 758,2 |
| 520 | 0,01147 | 773,8 | 0,01093 | 770,5 | 0,01044 | 767,4 |
| 530 | 0,01178 | 782,3 | 0,01124 | 779,2 | 0,01074 | 776,2 |
| 540 | 0,01209 | 790,5 | 0,01154 | 787,7 | 0,01103 | 784,8 |
| 550 | 0,01239 | 798,5 | 0,01183 | 795,9 | 0,01131 | 793,2 |
| 560 | 0,01267 | 806,4 | 0,01211 | 803,9 | 0,01158 | 801,3 |
| 570 | 0,01295 | 814,1 | 0,01238 | 811,7 | 0,01185 | 809,3 |
| 580 | 0,01322 | 821,6 | 0,01265 | 819,3 | 0,01211 | 817,1 |
| 590 | 0,01348 | 829,0 | 0,01291 | 826,8 | 0,01237 | 824,7 |
| 600 | 0,01375 | 836,6 | 0,01316 | 834,3 | 0,01262 | 832,3 |
| 610 | 0,01400 | 843,7 | 0,01341 | 841,7 | 0,01286 | 839,7 |
| 620 | 0,01425 | 850,7 | 0,01365 | 848,8 | 0,01310 | 846,9 |
| 630 | 0,01450 | 857,7 | 0,01389 | 855,9 | 0,01334 | 854,1 |
| 640 | 0,01475 | 864,6 | 0,01413 | 862,8 | 0,01357 | 861,1 |
| 650 | 0,01499 | 871,4 | 0,01436 | 869,8 | 0,01380 | 868,1 |
| 660 | 0,01523 | 878,2 | 0,01459 | 876,6 | 0,01402 | 875,0 |
| 670 | 0,01547 | 884,9 | 0,01482 | 883,3 | 0,01423 | 881,8 |
| 680 | 0,01570 | 891,6 | 0,01505 | 890,1 | 0,01445 | 888,5 |
| 690 | 0,01593 | 898,2 | 0,01528 | 896,8 | 0,01467 | 895,3 |
| 700 | 0,01615 | 904,8 | 0,01550 | 903,4 | 0,01489 | 902,0 |
| 710 | 0,01637 | 911,3 | 0,01572 | 910,0 | 0,01511 | 908,6 |
| 720 | 0,01659 | 917,8 | 0,01593 | 916,5 | 0,01532 | 915,2 |
| 730 | 0,01681 | 924,3 | 0,01615 | 923,0 | 0,01553 | 921,8 |
| 740 | 0,01703 | 930,7 | 0,01636 | 929,5 | 0,01573 | 928,3 |
| 750 | 0,01725 | 937,0 | 0,01657 | 935,8 | 0,01593 | 934,7 |
| | $p = 290$ ama 3 | | $p = 300$ ama 3 | | $p = 310$ ama 3 | |
| 0 | 0,0009864 | 6,8 | 0,0009859 | 7,1 | 0,0009854 | 7,3 |
| 10 | 0,0009885 | 16,6 | 0,0009871 | 16,8 | 0,0009867 | 17,0 |
| 20 | 0,0009896 | 26,4 | 0,0009892 | 26,6 | 0,0009888 | 26,8 |
| 30 | 0,0009924 | 36,2 | 0,0009920 | 36,4 | 0,0009916 | 36,6 |
| 40 | 0,0009968 | 46,0 | 0,0009954 | 46,2 | 0,0009950 | 46,4 |

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|---|---|---|---|---|---|---|
| 50 | 0,0009999 | 55,8 | 0,0009995 | 56,0 | 0,0009991 | 56,2 |
| 60 | 0,0010046 | 65,6 | 0,0010042 | 65,8 | 0,0010038 | 66,0 |
| 70 | 0,0010100 | 75,5 | 0,0010096 | 75,7 | 0,0010092 | 75,9 |
| 80 | 0,0010159 | 85,3 | 0,0010154 | 85,5 | 0,0010150 | 85,7 |
| 90 | 0,0010225 | 95,6 | 0,0010220 | 95,5 | 0,0010216 | 95,7 |
| 100 | 0,0010296 | 105,3 | 0,0010291 | 105,5 | 0,0010287 | 105,7 |
| 110 | 0,0010372 | 115,2 | 0,0010367 | 115.4 | 0,0010362 | 115,6 |
| 120 | 0,0010453 | 125,2 | 0,0010448 | 125,4 | 0.0010443 | 125,6 |
| 130 | 0,0010541 | 135,2 | 0,0010535 | 135,3 | 0,0010530 | 135,5 |
| 140 | 0,0010634 | 145,2 | 0,0010628 | 145,3 | 0,0010623 | 145,5 |
| 150 | 0,0010732 | 155,3 | 0,0010726 | 155,4 | 0,0010720 | 155,6 |
| 160 | 0,0010836 | 165,4 | 0,0010830 | 165,5 | 0,0010824 | 165,6 |
| 170 | 0,0010946 | 175,5 | 0,0010940 | 175,6 | 0,0010934 | 175,7 |
| 180 | 0,0011063 | 185,7 | 0,0011057 | 185,8 | 0,0011050 | 185,9 |
| 190 | 0,0011188 | 195,9 | 0,0011181 | 196,0 | 0,0011173 | 196,1 |
| 200 | 0.0011320 | 206,2 | 0.0011312 | 206,3 | 0,0011304 | 206,4 |
| 210 | 0,0011461 | 216,6 | 0,0011452 | 216,7 | 0,0011443 | 216,8 |
| 220 | 0,0011611 | 227,2 | 0,0011602 | 227,2 | 0,0011592 | 227,3 |
| 230 | 0,0011770 | 237,9 | 0,0011760 | 237,9 | 0,0011750 | 238,0 |
| 240 | 0,0011943 | 248,7 | 0,0011932 | 248,7 | 0,0011920 | 248,8 |
| 250 | 0,0012129 | 259,7 | 0,0012117 | 259.7 | 0,0012104 | 259,8 |
| 260 | 0,0012330 | 270,8 | 0,0012316 | 270,8 | 0,0012302 | 270,8 |
| 270 | 0,0012550 | 282,1 | 0,0012533 | 282,1 | 0,0012517 | 282,1 |
| 280 | 0,0012791 | 293,6 | 0,0012772 | 293,6 | 0,0012753 | 293,6 |
| 290 | 0,0013057 | 305,4 | 0,0013035 | 305,3 | 0,0013015 | 305,2 |
| 300 | 0,0013353 | 317,4 | 0,0013327 | 317,2 | 0,0013303 | 317,1 |
| 310 | 0,001369 | 329,7 | 0,001366 | 329,5 | 0,001362 | 329,4 |
| 320 | 0,001406 | 342,4 | 0,001403 | 342,2 | 0,001399 | 342,0 |
| 330 | 0,001450 | 355,8 | 0,001446 | 355,5 | 0,001142 | 355,4 |
| 340 | 0,001501 | 369,9 | 0,001496 | 369,5 | 0,001492 | 369,3 |
| 350 | 0,001568 | 384,9 | 0,001560 | 384,4 | 0 001552 | 383,8 |
| 360 | 0,001646 | 401,0 | 0,001634 | 400,1 | 0,001623 | 399,1 |
| 370 | 0,00176 | 419,3 | 0,00174 | 417,8 | 0,001724 | 416,3 |
| 380 | 0,00194 | 442,1 | 0,00190 | 438,9 | 0,00187 | 436,2 |
| 390 | 0,00232 | 477,2 | 0,00220 | 468,5 | 0,00212 | 462,7 |
| 400 | 0,00363 | 547,8 | 0,00308 | 524,0 | 0,00272 | 505,6 |
| 410 | 0,00485 | 597,9 | 0,00432 | 581,8 | 0,00384 | 565,1 |
| 420 | 0,00568 | 627,5 | 0,00521 | 616,3 | 0,00476 | 604,0 |
| 430 | 0,00635 | 650,3 | 0,00590 | 641,6 | 0,00547 | 632,5 |
| 440 | 0,00691 | 668,7 | 0,00646 | 661,4 | 0,00605 | 653,8 |
| 450 | 0,00741 | 684,6 | 0,00697 | 678,3 | 0,00657 | 671,8 |
| 460 | 0,00785 | 698,7 | 0,00742 | 693,1 | 0,00702 | 687,4 |
| 470 | 0,00826 | 711,5 | 0,00783 | 706,5 | 0,00743 | 701,5 |
| 480 | 0,00864 | 723,3 | 0,00822 | 718,8 | 0,00782 | 714,3 |
| 490 | 0,00900 | 734,3 | 0,00858 | 730,3 | 0,00818 | 726,1 |
| 500 | 0,00934 | 744,8 | 0,00892 | 741,0 | 0.00851 | 737,1 |
| 510 | 0,00966 | 754,7 | 0,00922 | 751,2 | 0,00882 | 747,6 |
| 520 | 0,00997 | 764,1 | 0,00953 | 760,8 | 0,00912 | 757,5 |
| 530 | 0,01026 | 773,2 | 0,00982 | 770,1 | 0,00941 | 766,9 |
| 540 | 0,01054 | 781,9 | 0,01010 | 779,0 | 0,00969 | 776,0 |
| 550 | 0,01083 | 790,4 | 0,01038 | 787,6 | 0,00996 | 784,8 |
| 560 | 0,01110 | 798,7 | 0,01064 | 796,0 | 0,01022 | 793,4 |
| 570 | 0,01136 | 806,8 | 0,01091 | 804,3 | 0,01048 | 801,8 |
| 580 | 0,01162 | 814,8 | 0,01116 | 812,4 | 0,01072 | 810,1 |
| 590 | 0,1187 | 822,5 | 0,01140 | 820,3 | 0,01096 | 818,1 |

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|---|---|---|---|---|---|---|
| 600 | 0,01211 | 830,2 | 0,01163 | 828,1 | 0,01120 | 826,0 |
| 610 | 0,01234 | 837,6 | 0,01186 | 835,7 | 0,01142 | 833,7 |
| 620 | 0,01257 | 844,9 | 0,01208 | 843,1 | 0,01165 | 841,2 |
| 630 | 0,01280 | 852,2 | 0,01230 | 850,4 | 0,01187 | 848,6 |
| 640 | 0,01303 | 859,4 | 0,01252 | 857,6 | 0,01208 | 855,8 |
| 650 | 0,01326 | 866,4 | 0,01274 | 864,8 | 0,01230 | 863,1 |
| 660 | 0,01348 | 873,4 | 0,01296 | 871,8 | 0,01251 | 870,2 |
| 670 | 0,01370 | 880,3 | 0,01318 | 878,8 | 0,01272 | 877,2 |
| 680 | 0,01391 | 887,1 | 0,01340 | 885,6 | 0,01292 | 884,2 |
| 690 | 0,01412 | 893,9 | 0,01361 | 892,5 | 0,01311 | 891,0 |
| 700 | 0,01433 | 900,6 | 0,01381 | 899,3 | 0,01332 | 897,9 |
| 710 | 0,01454 | 907,3 | 0,01401 | 906,0 | 0,01352 | 904,7 |
| 720 | 0,01474 | 914,0 | 0,01421 | 912,7 | 0,01371 | 911,4 |
| 730 | 0,01494 | 920,6 | 0,01441 | 919,3 | 0,01389 | 918,0 |
| 740 | 0,01514 | 927,1 | 0,01460 | 925,8 | 0,01409 | 924,6 |
| 750 | 0,01534 | 933,5 | 0,01479 | 932,3 | 0,01428 | 931,2 |
| | $p = 320$ ama (3) | | $p = 330$ ama (3) | | $p = 340$ ama (3) | |
| 0 | 0,0009850 | 7,5 | 0,0009845 | 7,8 | 0,0009841 | 8,0 |
| 10 | 0,0009863 | 17,2 | 0,0009858 | 17,5 | 0,0009855 | 17,7 |
| 20 | 0,0009884 | 27,0 | 0,0009880 | 27,2 | 0,0009876 | 27,5 |
| 30 | 0,0009912 | 36,8 | 0,0009908 | 37,0 | 0,0009904 | 37,2 |
| 40 | 0,0009946 | 46,6 | 0,0009942 | 46,8 | 0,0009938 | 47,0 |
| 50 | 0,0009987 | 56,4 | 0,0009983 | 56,6 | 0,0009979 | 56,8 |
| 60 | 0,0010034 | 66,2 | 0,0010030 | 66,4 | 0,0010026 | 66,6 |
| 70 | 0,0010087 | 76,1 | 0,0010083 | 76,3 | 0,0010079 | 76,5 |
| 80 | 0,0010145 | 85,9 | 0,0010142 | 86,1 | 0,0010137 | 86,1 |
| 90 | 0,0010211 | 95,9 | 0,0010207 | 96,1 | 0,0010202 | 96,2 |
| 100 | 0,0010282 | 105,9 | 0,0010278 | 106,0 | 0,0010273 | 106,2 |
| 110 | 0,0010357 | 115,8 | 0,0010353 | 115,9 | 0,0010348 | 116,1 |
| 120 | 0,0010438 | 125,7 | 0,0010433 | 125,9 | 0,0010428 | 126,1 |
| 130 | 0,0010525 | 135,6 | 0,0010519 | 135,8 | 0,0010514 | 136,0 |
| 140 | 0,0010617 | 145,6 | 0,0010612 | 145,8 | 0,0010606 | 145,9 |
| 150 | 0,0010715 | 155,7 | 0,0010709 | 155,9 | 0,0010704 | 156,0 |
| 160 | 0,0010818 | 165,7 | 0,0010812 | 165,8 | 0,0010807 | 166,0 |
| 170 | 0,0010927 | 175,9 | 0,0010921 | 176,0 | 0,0010915 | 176,2 |
| 180 | 0,0011043 | 186,1 | 0,0011036 | 186,2 | 0,0011030 | 186,3 |
| 190 | 0,0011166 | 196,2 | 0,0011158 | 196,4 | 0,0011152 | 196,5 |
| 200 | 0,0011295 | 206,5 | 0,0011288 | 206,6 | 0,0011280 | 206,8 |
| 210 | 0,0011434 | 216,9 | 0,0011426 | 217,0 | 0,0011417 | 217,1 |
| 220 | 0,0011582 | 227,4 | 0,0011573 | 227,5 | 0,0011563 | 227,6 |
| 230 | 0,0011740 | 238,1 | 0,0011730 | 238,1 | 0,0011719 | 238,2 |
| 240 | 0,0011909 | 248,8 | 0,0011898 | 248,9 | 0,0011886 | 249,0 |
| 250 | 0,0012091 | 259,8 | 0,0012079 | 259,8 | 0,0012066 | 259,9 |
| 260 | 0,0012288 | 270,9 | 0,0012274 | 270,9 | 0,0012259 | 270,9 |
| 270 | 0,0012501 | 282,1 | 0,0012485 | 282,1 | 0,0012468 | 282,1 |
| 280 | 0,0012736 | 293,5 | 0,0012718 | 293,5 | 0,0012699 | 293,5 |
| 290 | 0,0012994 | 305,2 | 0,0012974 | 305,1 | 0,0012953 | 305,1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 300 | 0,0013279 | 317,0 | 0,0013254 | 316,9 | 0,0013240 | 316,9 |
| 310 | 0,001359 | 329,2 | 0,001356 | 329,1 | 0,001354 | 329,0 |
| 320 | 0,001395 | 341,9 | 0,001392 | 341,5 | 0,001388 | 341,6 |
| 330 | 0,001437 | 355,1 | 0,001433 | 354,9 | 0,001428 | 354,6 |
| 340 | 0,001485 | 368,9 | 0,001480 | 368,5 | 0,001474 | 368,1 |
| 350 | 0,001544 | 383,2 | 0,001537 | 382,6 | 0,001530 | 382,1 |
| 360 | 0,001612 | 398,2 | 0,001603 | 397,4 | 0,001593 | 396,7 |
| 370 | 0,001707 | 414,9 | 0,001694 | 413,8 | 0,001680 | 412,9 |
| 380 | 0,00184 | 434,0 | 0,00182 | 432,6 | 0,00179 | 431,3 |
| 390 | 0,00206 | 458,3 | 0,00201 | 455,1 | 0,00197 | 452,7 |
| 400 | 0,00249 | 493,5 | 0,00234 | 486,3 | 0,00225 | 481,3 |
| 410 | 0,00340 | 548,7 | 0,00304 | 532,6 | 0,00279 | 529,4 |
| 420 | 0,00434 | 591,0 | 0,00395 | 579,0 | 0,00359 | 566,7 |
| 430 | 0,00506 | 623,0 | 0,00468 | 613,3 | 0,00433 | 603,4 |
| 440 | 0,00566 | 646,0 | 0,00529 | 637,9 | 0,00493 | 629,6 |
| 450 | 0.00618 | 665,0 | 0,00582 | 658,1 | 0,00547 | 651,0 |
| 460 | 0.00664 | 681,6 | 0,00628 | 675,5 | 0,00594 | 669,3 |
| 470 | 0,00706 | 696,3 | 0,00669 | 691,1 | 0,00636 | 685,5 |
| 480 | 0,00744 | 709,6 | 0,00708 | 704,8 | 0,00675 | 700,0 |
| 490 | 0.00780 | 721,9 | 0.00745 | 717,6 | 0,00712 | 713,2 |
| 500 | 0.00813 | 733,2 | 0,00778 | 729,3 | 0,00745 | 725,3 |
| 510 | 0,00844 | 744,0 | 0,00808 | 740,3 | 0,00775 | 736,6 |
| 520 | 0,00874 | 754,1 | 0,00838 | 750,7 | 0,00804 | 747,3 |
| 530 | 0,00902 | 763,8 | 0,00866 | 760,6 | 0,00832 | 757,4 |
| 540 | 0,00930 | 773,1 | 0,00894 | 770,1 | 0,00859 | 767,1 |
| 550 | 0,00956 | 782,1 | 0,00920 | 779,3 | 0,00885 | 776,4 |
| 560 | 0,00982 | 790,8 | 0,00945 | 788,1 | 0,00910 | 785,5 |
| 570 | 0,01007 | 799,3 | 0,00970 | 796,8 | 0 00934 | 794,3 |
| 580 | 0,01032 | 807,7 | 0,00993 | 805,3 | 0,00959 | 802,9 |
| 590 | 0,01055 | 815,8 | 0,01017 | 813,6 | 0,00980 | 811,3 |
| 600 | 0,01078 | 823,8 | 0,01040 | 821,6 | 0,01003 | 819,4 |
| 610 | 0,01100 | 831,6 | 0,01061 | 829,6 | 0,01024 | 827,5 |
| 620 | 0,01122 | 839,2 | 0,01083 | 837,3 | 0,01045 | 835,3 |
| 630 | 0,01144 | 846,6 | 0,01104 | 844,9 | 0,01066 | 843,0 |
| 640 | 0,01165 | 854,0 | 0,01125 | 852,3 | 0,01087 | 850,5 |
| 650 | 0,01186 | 861,4 | 0,01145 | 859,7 | 0,01107 | 858,0 |
| 660 | 0,01207 | 868,6 | 0,01166 | 867,0 | 0,01127 | 865,3 |
| 670 | 0,01227 | 875,6 | 0,01185 | 874,1 | 0,01146 | 872,5 |
| 680 | 0,01247 | 882,7 | 0,01205 | 881,2 | 0,01165 | 879,6 |
| 690 | 0,01267 | 889,6 | 0,01224 | 888,1 | 0,01184 | 886,7 |
| 700 | 0,01286 | 896,5 | 0,01243 | 895,1 | 0,01203 | 893,7 |
| 710 | 0,01305 | 903,3 | 0,01262 | 902,1 | 0,01221 | 900,7 |
| 720 | 0,01324 | 910,1 | 0,01281 | 908,8 | 0,01239 | 906,7 |
| 730 | 0,01343 | 916,8 | 0,01299 | 915,5 | 0,01257 | 914,3 |
| 740 | 0,01362 | 923,4 | 0,01317 | 922,2 | 0,01275 | 920,9 |
| 750 | 0,01381 | 930,0 | 0,01335 | 928,8 | 0,01292 | 927,6 |
| | $p = 350$ ama 3 | | $p = 360$ ama 3 | | $p = 370$ ama 3 | |
| 0 | 0,0009836 | 8,2 | 0,0009831 | 8,4 | 0,0009827 | 8,6 |
| 10 | 0,0009851 | 17,9 | 0,0009846 | 18,1 | 0,0009842 | 18,3 |
| 20 | 0,0009872 | 27,7 | 0,0009868 | 27,9 | 0,0009864 | 28,1 |
| 30 | 0,0009900 | 37,4 | 0,0009896 | 37,7 | 0,0009892 | 37,9 |
| 40 | 0,0009934 | 47,2 | 0,0009930 | 47,4 | 0,0009926 | 47,6 |

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|---|---|---|---|---|---|---|
| 50 | 0,0009975 | 57,0 | 0,0009971 | 57,2 | 0,0009967 | 57,4 |
| 60 | 0,0010022 | 66,8 | 0,0010018 | 67,0 | 0,0010014 | 67,2 |
| 70 | 0,0010075 | 76,7 | 0,0010071 | 76,9 | 0,0010067 | 77,1 |
| 80 | 0,0010133 | 86,4 | 0,0010129 | 86,6 | 0,0010125 | 86,8 |
| 90 | 0,0010198 | 96,4 | 0,0010194 | 96,7 | 0,0010189 | 96,8 |
| 100 | 0,0010268 | 106,4 | 0,0010264 | 106,6 | 0,0010259 | 106,8 |
| 110 | 0,0010343 | 116,3 | 0,0010338 | 116,4 | 0,0010333 | 116,6 |
| 120 | 0,0010423 | 126,2 | 0,0010418 | 126,4 | 0,0010413 | 126,6 |
| 130 | 0,0010509 | 136,1 | 0,0010504 | 136,3 | 0,0010499 | 136,4 |
| 140 | 0,0010601 | 146,1 | 0,0010596 | 146,2 | 0,0010591 | 146,4 |
| 150 | 0,0010698 | 156,3 | 0,0010693 | 156,3 | 0,0010688 | 156,5 |
| 160 | 0,0010801 | 166,1 | 0,0010795 | 166,3 | 0,0010789 | 166,4 |
| 170 | 0,0010909 | 176,3 | 0,0010903 | 176,4 | 0,0010897 | 176,6 |
| 180 | 0,0011023 | 186,5 | 0,0011017 | 186,6 | 0,0011010 | 186,7 |
| 190 | 0,0011144 | 196,6 | 0,0011137 | 196,8 | 0,0011130 | 196,9 |
| 200 | 0,0011272 | 206,9 | 0,0011264 | 207,0 | 0,0011255 | 207,1 |
| 210 | 0,0011408 | 217,2 | 0,0011400 | 217,3 | 0,0011391 | 217,4 |
| 220 | 0,0011553 | 227,7 | 0,0011544 | 227,8 | 0,0011535 | 227,9 |
| 230 | 0,0011708 | 238,3 | 0,0011698 | 238,4 | 0,0011688 | 238,5 |
| 240 | 0,0011875 | 249,0 | 0,0011864 | 249,1 | 0,0011853 | 249,2 |
| 250 | 0,0012054 | 260,0 | 0,0012041 | 260,0 | 0,0012029 | 260,1 |
| 260 | 0,0012246 | 271,0 | 0,0012232 | 271,0 | 0,0012218 | 271,0 |
| 270 | 0,0012455 | 282,1 | 0,0012440 | 282,2 | 0,0012423 | 282,2 |
| 280 | 0,0012683 | 293,5 | 0,0012667 | 293,5 | 0,0012648 | 293,5 |
| 290 | 0,0012933 | 305,1 | 0,0012914 | 305,0 | 0,0012894 | 305,0 |
| 300 | 0,001321 | 316,9 | 0,001319 | 316,7 | 0,001316 | 316,7 |
| 310 | 0,001351 | 328,9 | 0,001348 | 328,8 | 0,001346 | 328,7 |
| 320 | 0,001386 | 341,4 | 0,001383 | 341,3 | 0,001379 | 341,1 |
| 330 | 0,001424 | 354,4 | 0,001420 | 354,2 | 0,001416 | 353,9 |
| 340 | 0,001469 | 367,8 | 0,001464 | 367,5 | 0,001460 | 367,1 |
| 350 | 0,001524 | 381,6 | 0,001518 | 381,1 | 0,001511 | 380,6 |
| 360 | 0,001584 | 396,1 | 0,001576 | 395,5 | 0,001568 | 394,9 |
| 370 | 0,001667 | 412,0 | 0,001656 | 411,2 | 0,001644 | 410,5 |
| 380 | 0,00177 | 430,0 | 0,00176 | 428,9 | 0,00174 | 427,6 |
| 390 | 0,00194 | 450,6 | 0,00190 | 449,0 | 0,00188 | 447,3 |
| 400 | 0,00217 | 477,4 | 0,00211 | 474,2 | 0,00206 | 471,2 |
| 410 | 0,00260 | 511,0 | 0,00246 | 505,1 | 0,00236 | 499,0 |
| 420 | 0,00329 | 554,9 | 0,00302 | 543,7 | 0,00282 | 534,0 |
| 430 | 0,00399 | 593,4 | 0,00370 | 582,6 | 0,00343 | 572,0 |
| 440 | 0,00460 | 621,2 | 0,00430 | 612,6 | 0,00402 | 604,0 |
| 450 | 0,00514 | 643,7 | 0,00484 | 636,4 | 0,00456 | 628,8 |
| 460 | 0,00562 | 663,0 | 0,00532 | 656,5 | 0,00504 | 649,9 |
| 470 | 0,00606 | 679,9 | 0,00575 | 674,2 | 0,00547 | 668,4 |
| 480 | 0,00646 | 695,0 | 0,00614 | 689,9 | 0,00586 | 684,7 |
| 490 | 0,00681 | 708,7 | 0,00651 | 704,1 | 0,00623 | 699,5 |
| 500 | 0,00713 | 721,2 | 0,00684 | 717,1 | 0,00656 | 712,9 |
| 510 | 0,00743 | 732,8 | 0,00713 | 729,1 | 0,00686 | 725,2 |
| 520 | 0,00772 | 743,8 | 0,00742 | 740,3 | 0,00714 | 736,8 |
| 530 | 0,00800 | 754,2 | 0,00770 | 751,0 | 0,00741 | 747,7 |
| 540 | 0,00827 | 764,1 | 0,00796 | 761,1 | 0,00767 | 758,0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 550 | 0,00852 | 773,6 | 0,00821 | 770,8 | 0,00792 | 767,9 |
| 560 | 0,00876 | 782,8 | 0,00845 | 780,1 | 0,00816 | 777,4 |
| 570 | 0,00901 | 791,8 | 0,00869 | 789,2 | 0,00839 | 786,7 |
| 580 | 0,00924 | 800,5 | 0,00892 | 798,1 | 0,00862 | 795,6 |
| 590 | 0,00946 | 809,0 | 0,00914 | 806,7 | 0,00884 | 804,3 |
| 600 | 0,00969 | 817,2 | 0,00936 | 815,0 | 0,00906 | 812,8 |
| 610 | 0,00989 | 825,4 | 0,00956 | 823,3 | 0,00925 | 821,2 |
| 620 | 0,01010 | 833,3 | 0,00977 | 831,3 | 0,00945 | 829,3 |
| 630 | 0,01031 | 841,1 | 0,00997 | 839,2 | 0,00965 | 837,3 |
| 640 | 0,01051 | 848,7 | 0,01017 | 846,9 | 0,00985 | 845,0 |
| 650 | 0,01071 | 856,2 | 0,01036 | 854,5 | 0,01004 | 852,8 |
| 660 | 0,01090 | 863,7 | 0,01056 | 862,0 | 0,01023 | 860,3 |
| 670 | 0,01109 | 870,9 | 0,01074 | 869,3 | 0,01041 | 867,8 |
| 680 | 0,01128 | 878,1 | 0,01093 | 876,6 | 0,01059 | 875,0 |
| 690 | 0,01146 | 885,3 | 0,01111 | 883,8 | 0,01077 | 882,3 |
| 700 | 0,01165 | 892,3 | 0,01129 | 890,9 | 0,01095 | 889,5 |
| 710 | 0,01183 | 899,3 | 0,01147 | 898,0 | 0,01112 | 896,6 |
| 720 | 0,01200 | 906,2 | 0,01164 | 904,9 | 0,01130 | 903,5 |
| 730 | 0,01218 | 913,0 | 0,01181 | 911,8 | 0,01146 | 910,5 |
| 740 | 0,01235 | 919,5 | 0,01198 | 918,5 | 0,01163 | 917,3 |
| 750 | 0,01252 | 926,5 | 0,01215 | 925,3 | 0,01179 | 924,1 |
| | $p = 380$ ama (3) | | $p = 390$ ama (3) | | $p = 400$ ama (3) | |
| 0 | 0,0009822 | 8,9 | 0,0009818 | 9,1 | 0,0009813 | 9,3 |
| 10 | 0,0009838 | 18,7 | 0,0009835 | 18,8 | 0,0009830 | 19,0 |
| 20 | 0,0009860 | 28,3 | 0,0009856 | 28,5 | 0,0009852 | 28,7 |
| 30 | 0,0009888 | 38,1 | 0,0009884 | 38,3 | 0,0009880 | 38,5 |
| 40 | 0,0009922 | 47,8 | 0,0009918 | 48,0 | 0,0009914 | 48,2 |
| 50 | 0,0009963 | 57,6 | 0,0009959 | 57,8 | 0,0009955 | 58,0 |
| 60 | 0,0010010 | 67,4 | 0,0010006 | 67,6 | 0,0010002 | 67,8 |
| 70 | 0,0010062 | 77,2 | 0,0010058 | 77,4 | 0,0010054 | 77,6 |
| 80 | 0,0010120 | 87,0 | 0,0010116 | 87,2 | 0,0010112 | 87,4 |
| 90 | 0,0010185 | 97,0 | 0,0010181 | 97,2 | 0,0010177 | 97,3 |
| 100 | 0,0010255 | 106,9 | 0,0010251 | 107,1 | 0,0010247 | 107,3 |
| 110 | 0,0010329 | 116,8 | 0,0010325 | 117,0 | 0,0010322 | 117,2 |
| 120 | 0,0010408 | 126,8 | 0,0010405 | 126,9 | 0,0010401 | 127,1 |
| 130 | 0,0010495 | 136,6 | 0,0010490 | 136,8 | 0,0010485 | 136,9 |
| 140 | 0,0010586 | 146,6 | 0,0010580 | 146,7 | 0,0010576 | 146,9 |
| 150 | 0,0010682 | 156,6 | 0,0010678 | 156,8 | 0,0010672 | 156,9 |
| 160 | 0,0010784 | 166,6 | 0,0010778 | 166,7 | 0,0010772 | 166,9 |
| 170 | 0,0010891 | 176,7 | 0,0010884 | 176,9 | 0,0010879 | 177,0 |
| 180 | 0,0011003 | 186,9 | 0,0010997 | 187,0 | 0,0010991 | 187,1 |
| 190 | 0,0011123 | 197,0 | 0,0011116 | 197,1 | 0,0011109 | 197,2 |
| 200 | 0,0011248 | 207,2 | 0,0011241 | 207,4 | 0,0011234 | 207,5 |
| 210 | 0,0011382 | 217,6 | 0,0011375 | 217,7 | 0,0011367 | 217,8 |
| 220 | 0,0011526 | 228,0 | 0,0011518 | 228,1 | 0,0011509 | 228,2 |
| 230 | 0,0011679 | 238,6 | 0,0011669 | 238,6 | 0,0011660 | 238,7 |
| 240 | 0,0011842 | 249,2 | 0,0011831 | 249,3 | 0,0011821 | 249,4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 250 | 0,0012018 | 260,1 | 0,0012005 | 260,2 | 0,0011994 | 260,2 |
| 260 | 0,0012207 | 271,1 | 0,0012191 | 271,1 | 0,0012178 | 271 |
| 270 | 0,0012409 | 282,2 | 0,0012392 | 282,2 | 0,0012379 | 282,2 |
| 280 | 0,0012632 | 293,5 | 0,0012614 | 293,5 | 0,0012599 | 293,5 |
| 290 | 0,0012875 | 304,9 | 0,0012855 | 304,9 | 0,0012838 | 304,9 |
| 300 | 0,001314 | 316,5 | 0,0013120 | 316,5 | 0,001309 | 316,4 |
| 310 | 0,001344 | 328,5 | 0,001342 | 328,3 | 0,001339 | 328,1 |
| 320 | 0,001376 | 340,8 | 0,001373 | 340,5 | 0,001370 | 340,2 |
| 330 | 0,001413 | 353,5 | 0,001410 | 353,2 | 0,001407 | 352,8 |
| 340 | 0,001455 | 366,6 | 0,001450 | 366,2 | 0,001446 | 365,7 |
| 350 | 0,001505 | 380,0 | 0,001499 | 379,5 | 0,001493 | 378,9 |
| 360 | 0,001561 | 394,3 | 0,001554 | 393,6 | 0,001548 | 392,9 |
| 370 | 0,001634 | 409,7 | 0,001624 | 408,9 | 0,001616 | 407,9 |
| 380 | 0,00173 | 426,3 | 0,001713 | 425,1 | 0,001704 | 423,9 |
| 390 | 0,00185 | 445,7 | 0,00183 | 443,9 | 0,00180 | 442,2 |
| 400 | 0,00202 | 468,3 | 0,00198 | 465,5 | 0,00195 | 462,6 |
| 410 | 0,00226 | 494,2 | 0,00219 | 490,1 | 0,00213 | 486,3 |
| 420 | 0,00266 | 525,8 | 0,00254 | 520,2 | 0,00243 | 514,6 |
| 430 | 0,00320 | 562,4 | 0,00301 | 553,4 | 0,00286 | 546,0 |
| 440 | 0,00379 | 595,3 | 0,00356 | 586,8 | 0,00337 | 578,5 |
| 450 | 0,00432 | 621,3 | 0,00407 | 613,9 | 0,00386 | 606,7 |
| 460 | 0,00478 | 643,3 | 0,00453 | 636,7 | 0,00430 | 630,2 |
| 470 | 0,00521 | 662,5 | 0,00496 | 656,6 | 0,00472 | 650,7 |
| 480 | 0,00560 | 679,5 | 0,00535 | 674,3 | 0,00512 | 669,0 |
| 490 | 0,00597 | 694,9 | 0,00571 | 690,1 | 0,00547 | 685,4 |
| 500 | 0,00629 | 708,7 | 0,00604 | 704,4 | 0,00580 | 700,1 |
| 510 | 0,00659 | 721,4 | 0,00634 | 717,5 | 0,00610 | 713,6 |
| 520 | 0,00687 | 733,3 | 0,00662 | 729,7 | 0,00638 | 726,1 |
| 530 | 0,00714 | 744,4 | 0,00688 | 741,1 | 0,00664 | 737,8 |
| 540 | 0,00740 | 755,0 | 0,00714 | 751,9 | 0,00690 | 748,8 |
| 550 | 0,00765 | 765,0 | 0,00738 | 762,2 | 0,00714 | 759,3 |
| 560 | 0,00788 | 774,7 | 0,00762 | 772,0 | 0,00737 | 769,3 |
| 570 | 0,00811 | 784,1 | 0,00785 | 781,5 | 0,00760 | 778,9 |
| 580 | 0,00833 | 793,2 | 0,00806 | 790,7 | 0,00781 | 788,3 |
| 590 | 0,00855 | 802,0 | 0,00828 | 799,6 | 0,00802 | 797,3 |
| 600 | 0,00877 | 810,6 | 0,00849 | 808,3 | 0,00822 | 806,1 |
| 610 | 0,00895 | 819,0 | 0,00867 | 816,9 | 0,00842 | 814,7 |
| 620 | 0,00915 | 827,3 | 0,00887 | 825,3 | 0,00861 | 823,2 |
| 630 | 0,00935 | 835,4 | 0,00907 | 833,5 | 0,00880 | 831,6 |
| 640 | 0,00954 | 843,2 | 0,00926 | 841,4 | 0,00898 | 839,5 |
| 650 | 0,00973 | 851,0 | 0,00944 | 849,2 | 0,00917 | 847,4 |
| 660 | 0,00992 | 858,6 | 0,00963 | 856,9 | 0,00935 | 855,2 |
| 670 | 0,01010 | 866,2 | 0,00980 | 864,6 | 0,00952 | 862,9 |
| 680 | 0,01028 | 873,5 | 0,00998 | 871,9 | 0,00970 | 870,4 |
| 690 | 0,01045 | 880,8 | 0,01015 | 879,4 | 0,00987 | 877,9 |
| 700 | 0,01063 | 888,1 | 0,01032 | 886,7 | 0,01003 | 885,3 |
| 710 | 0,01080 | 895,2 | 0,01049 | 893,9 | 0,01020 | 892,5 |
| 720 | 0,01097 | 902,3 | 0,01066 | 900,9 | 0,01036 | 899,6 |
| 730 | 0,01114 | 909,2 | 0,01082 | 907,9 | 0,01052 | 906,6 |
| 740 | 0,01130 | 916,1 | 0,01098 | 914,8 | 0,01068 | 913,6 |
| 750 | 0,01146 | 922,8 | 0,01114 | 921,7 | 0,01083 | 920,5 |

Key: (1). $m^3$/kg. (2). kcal/kg. (3). atm(abs.).

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Appendix III.

CALCULATION OF STEAM COOLERS.

A. Surface/skin steam coolers.

1. In contemporary boiler aggregates/units are applied surface/skin steam coolers with cooling of steam by feed or boiling (boiler) water (outside or arranged/located within drum).

During the cooling of steam by feed water regardless of the fact, saturated it or overheated, occurs partial condensation of steam. In the steam coolers with the boiling water the steam is not condensed, but only is decreased temperature. This difference it causes the need for the different procedures of calculation of steam coolers with the nonboiling and boiling cooling water.

2. Coefficient of heat transfer of cooled by feed water condenser-type attemperators, located in chamber/camera of saturated steam, and also in intermediate chambers/cameras in which speed of steam does not exceed 1.5 m/s, with outside diameter of coils 15-30

mm, by internalization diameter of chambers/cameras $\leqslant$300 mm and speeds of water $\leqslant$2.0 m/s, is designed by p tc empirical formula

$$k=1700w_{w} \text{ kcal/m}^2 \text{ hour deg} \quad (1)$$

where $w_{w}$ - average speed of water in coils (tubes) of steam cooler, determined according tc actual consumption of water through steam cooler, m/s.

At the speeds of water $w_{w}>2.0$ m/s the calculation of these steam coolers is conducted employing the general/common/total procedure, presented below in paragraphs 4-7.

3. Coefficient of heat transfer of vertical columned steam cooler LMZ (obsolete type), which is of 27 tubes Ø25x2 with mm and length of 1.9 m, included in column Ø250 mm with ascending current slowly moving water ($w_{w}$ =0.015-0.3 m/s in mean section of column) and descending motion of steam at pressure of steam p=30-35 atm(abs.) is calculated according tc empirical formula

$$k=900+7850\,w_{w} \text{ kcal/m}^2 \text{ hour deg.} \quad (2)$$

4. For all remaining steam coolers coefficient of heat transfer is determined from formula

$$k=\xi\frac{1}{\frac{1}{\alpha_1}+\frac{\delta_м}{\lambda_м}+\frac{1}{\alpha_2}}$$ kcal/m² hour deg, (3)

where $\alpha_1$ and $\alpha_2$ - heat-transfer coefficients from vapor to wall and from wall to water, kcal/m² hour deg; $\delta_м$ and $\lambda_м$ - thickness and coefficient of thermal conductivity of wall of ducts, m and kcal/m hour deg; value $\lambda_м$ takes as equal to 40 kcal/m hour deg; $\xi$ - coefficient of use of surface of heating steam cooler; for horizontal steam coolers, cooled by feed water, at pressure of steam 100 atm(abs.) and speeds of water $w_ж>2.5$ m/s, $\xi$=1.2; in remaining cases $\xi$=1.0.

5. Heat-transfer coefficient from steam to wall during cooling of tubes with feed water for steam coolers with horizontal bank of tubes, washed by vertical current of steam, is calculated according to formula

$$\alpha_1=0.5\beta\sqrt[4]{\frac{\gamma_ж^2\lambda_ж^3 r\,3600}{\mu_ж\,\delta t d}}=$$
$=\beta\alpha_0$ kcal/ ² hour deg, (4)

where $\alpha_0$ - heat-transfer coefficient from fixed vapor to wall of horizontal ducts, kcal/m² hour deg; $\beta$ - speed factor, which considers effect of motion of steam determined along auxiliary field of

nomogram XXIV into depending on complex $w_n^2\gamma_n$ and pressures of steam in chamber/camera of steam cooler p atm(abs.); with flow of tubes of steam cooler partially by ascending and partially descending flows of steam.

$$\beta = \frac{\beta^{верх} + \beta^{низ}}{2};$$

$\lambda_ж$ kcal/m hour deg; $\mu_ж$ kg/s m² and $\gamma_ж$ kg/m³ - coefficients of thermal conductivity and viscosity/ductility/toughness and specific gravity/weight of water on the line of saturation at a pressure of steam in the steam cooler; r - heat of vaporization at a pressure of steam in the steam cooler, kcal/kg; d - outside diameter of coils (tubes), m; δt - the temperature differential vapor - wall, °C; $w_n$ - speed of steam in the chamber/camera of steam cooler, m/s.

According to formula (4) is constructed nomogram XXIV.

6. speed of steam in chamber/camera of steam cooler $w_n$ is determined due to state of steam at entrance into steam cooler. Clear opening for the pass of steam is calculated for each horizontal series/row it is separately and neutralized proportional to the surfaces of heating series/rows according to the formula

$$F_{cp} = \frac{l\sum H}{\frac{H_1}{a_1+a_2} + \frac{H_2+H_3}{b_1+b_2+b_3} + \cdots + \frac{H_N}{c_1+c_2}}.$$

The diagram of the averaging of sections/cuts is shown in Fig. 8.

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7. For use of nomogram XXIV they are preliminarily assigned by value $\delta t$. After the determination of the total coefficient of heat transfer the preliminarily taken value is checked using the formula

$$\delta t = \frac{k(t_n - t_{\text{ж}})}{\alpha_1} \ ^\circ\text{C}, \qquad (5)$$

$t_n$ - saturation temperature at a pressure of steam in the steam cooler, by °C; $t_{\text{ж}}$ - mean temperature of water in the steam cooler, °C.

If the disagreement between the determined value $\delta t$ and that accepted does not preliminarily exceed +-25o/o, calculation is l ved without the changes; otherwise are counted over values of $\alpha_1$ and k. For the recalculation they take value $\delta t$, determined from formula (5) according to the data of the first calculation.

8. Heat-transfer coefficient from vapor to riding-crop during cooling of tubes with feed water for steam coolers with vertical beam of ducts, washed by longitudinal flow of steam, is calculated according to formula

$$\alpha_1 = \frac{2{,}5\lambda_{\text{ж}}}{\sqrt[3]{\frac{\mu_{\text{ж}} a_{\text{ж}}}{\gamma_{\text{ж}}}}} \left[1 + 0{,}003 w_n \sqrt{\frac{\gamma_n}{\gamma_{\text{ж}}}} \sqrt[3]{\frac{\gamma_{\text{ж}}}{\mu_{\text{ж}}}}\right] \text{ kcal/m}^2 \text{ hour deg}, \qquad (6)$$

where $a_ж$ - coefficient of thermal diffusivity of condensate, $m^2$/h.

Remaining designations - the same as in formula (4).

Speed of steam $w_n$ m/s in view of the insignificance of a change in the state of the latter is determined due to the state of steam at the entrance into the steam cooler.

According to formula (6) is constructed nomogram XXV.

9. Heat-transfer coefficient from vapor to wall during cooling of tubes with water with temperature, which exceeds temperature of saturation of cooled vapor, is determined on nomogram V.

10. Heat-transfer coefficient from wall to nonboiling water is determined on nomogram VI.

11. Coefficient of of heat transfer from wall to boiling water for carbonic ducts on which can be formed oxide film, is determined from formula

$$\alpha_2 = \frac{1}{\frac{1}{6.5p^{0.2}q^{0.7}} + 0.5\cdot 10^{-4}} \text{ kcal/m}^2 \text{ hour deg.} \quad (7)$$

For the high-alloyed noncorrosive ducts

$$\alpha_2 = 2.5p^{0.2}q^{0.7}$$ kcal/m² hour deg, (7a)

p - the pressure of water in steam cooler, atm(abs.); q the thermal surface load of heating steam cooler, kcal/m²the hour; its value should be to preliminarily assign, and after the determination of the coefficient of the heat transfer of steam cooler k tested in the formula

$$q = k(t_n - t_{xsn})$$ kcal/m² hour. (8)

In the presence of the disagreement by that accepted and that calculated of values q less than 25o/o, the calculation is leaved without the changes; otherwise are counted over values $\alpha_2$ and k. For the recalculation they take value q, determined from formula (8), according to the data of the first calculation.

According to formula (7) is constructed nomogram XXVI. From this nomogram is designed the heat emission from the ducts made of the carbon steel.

12. Temperature head is calculated according to common formula (7-66) or (7-67). During the cooling by feed water the temperature of

steam always takes as the equal to saturation temperature. During the cooling by the boiling water the temperature head is determined by actual final temperatures of steam.

13. Surface of heating steam coolers is determined according to average/mean (between internal and external) diameter of tubes.

14. When selecting of value of heat absorption of steam cooler one should consider that due to called by inclusion of steam coolers of increase temperature head in superheater calculated value of heat absorption of steam coolers, arranged/located in collector/receptacle of saturated steam or "into crosscut" of superheater, must exceed prescribed/assigned reduction in enthalpy of superheated steam. Tentatively this excess can be taken as the equal to 15-30o/c of the assigned magnitude.

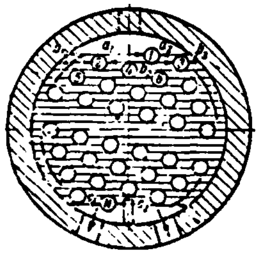

Fig. 8. Diagram of the averaging of sections/cuts for the pass of steam.

B. Spray-type desuperheaters.

15. Complexity of phenomena, which occur during evaporation of injection water, does not make it possible to at present design spray-type desuperheaters. Therefore are given below the short recommendations regarding the structural/design characteristics of the basic units of spray-type desuperheaters, developed on the basis of the results of the tests of the effective steam coolers.

With comparatively small drops/jumps in the pressures which can be used for the cooling-water supply, the velocity of the entrance of the latter into the steam cooler does not exert a substantial influence on the conditions of heat exchange.

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Therefore cooling water can be supplied into the steam cooler through the simple drilling by $\varnothing \leq 3$ mm in the wall of the inlet pipe; the speeds of pass through the drilling must be 15 m/s and it is above.

For guaranteeing the evaporation of cooling water it is necessary after the place of injection to provide for the straight/direct sections of ducts in long not less than 4 m. These sections can be furnished both horizontally and it is vertical. All over length of evaporative sections should be shielded the walls of duct by jacket with the clearance between the jacket and the wall, equal to 6-8 mm.

Appendix IV.

DETERMINATION OF THE CALCULATED TEMPERATURE OF THE METAL OF THE WALLS OF DUCTS.

1. Under calculated temperature of metal of ducts is understood great local value of temperature of wall, determined taking into account nonuniformity of heat absorption according to section/cut of flue and circumference of duct, and for tubes of superheater - also spreading heat on wall. The increases in the temperature of wall, called by deviations from the common mode/conditions of operation, in the calculation are not considered.

The calculated temperature of the metal of wall depends on the temperature of medium, which takes place in this section of duct, and the value of the thermal load of section. Therefore during testing of the temperature of the wall of the ducts of this heating surface should be selected the duct in which the temperature of medium and thermal load determine the maximum value of the temperature of wall.

When selecting of most dangerous pipe it is necessary to consider that in the corridor beams the greatest local thermal load always falls to the ducts of the first on the course of gases

series/row. In the checkered beams the number of the series/row in which are located the ducts with the greatest thermal load, depends on the relative transverse pitch of the ducts: with $s_1/d \geq 4.0$ the full load falls to the ducts of the second series/row; when $s_1/d \leq 2.5$ - to the ducts of the first series/row; at intermediate values of $s_1/d$ should be compared computed values of the maximum thermal load of the face grinding of the ducts of the first and second series/rows.

2. In basis of calculation of strength of ducts is accepted average/mean according to thickness temperature of metal of wall of most loaded duct:

$$t_{cm} = t + \Delta t_m + \beta\mu q_{макс}\left(\frac{\delta}{\lambda_m}\frac{1}{\beta+1} + \frac{1}{\alpha_2}\right) °C. \quad (1)$$

The utilized for determining maximum heat load $q_{макс}$ calculated temperature of the metal of the external wall of duct, having medium load $q_0$, is determined from the formula

$$t''_{cm} = t + \beta\mu q_0\left(\frac{\delta}{\lambda_m}\frac{2}{\beta+1} + \frac{1}{\alpha_2}\right) °C. \quad (2)$$

t - mean temperature of the taking place in the ducts medium for the designed section; it is accepted on p. 3, °C; $\Delta t_m$ - temperature excess of medium in that most loaded of the ducts above the average; it is determined on p. 5, °C; $\mu$ - coefficient of spreading the heat; for the boiling and economizer ducts $\mu$=1, and for the superheater ones - in p. 6; $q_{макс}$ - thermal load at the point of the maximum heat absorption of the most loaded duct; is determined on p. 4, kcal/m² the hour; $\delta$ - the wall thickness of duct, m; $\beta$ - ratio of the outside

diameter of duct to the internal:

$$\beta = \frac{d}{d - 2\delta};$$

$\lambda_{м}$ - the thermal conductivity of the metal of the wall; is accepted on Fig. 9 in the dependence on the temperature of wall, kcal/m hour deg; $\alpha_2$ - heat-transfer coefficient from the wall to the heating medium; is determined on p. 15, kcal/m² hour deg.

With the usually encountered thermal loads the calculated temperature of the wall of boiling and economizer ducts is accepted directly according to the recommendations of the norms of the calculation of the strength of the elements/cells of the boiler aggregates/units: for the heating pipes and the ducts of the radiation economizers

$$t_{cm} = t + 60°\ C;$$

for the ducts of the convective economizers

$$t_{cm} = t + 30°\ C.$$

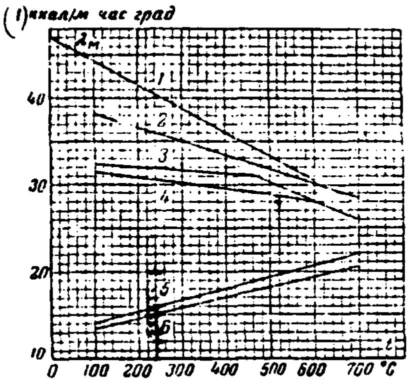


Fig. 9. The thermal conductivity of boiler steel $\lambda_м$ kcal/h deg in depending on temperature 1 - st. 20; 2 - 15M; 20M; 12MKh; 15KhM; 20KhM; 30KhMA; 12KhMF; 3 - 10Kh2MF (EI-531); 10Kh2MB (EI-454); 4 - 12Kh5M; 5 - Ya1T; 6 - EI-257.

Key: (1). kcal/m hour deg.

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With thermal loads $q_{макс}>800\cdot10^3$ kcal/m²h for the heating pipes and $q_{макс}> 300\cdot10^3$ kcal/m²h for the ducts of radiation economizers the temperature of wall is designed from formula (1).

3. Mean temperature of taking place in ducts medium for evaporative heating surfaces takes as equal to boiling point, and for superheaters and economizers - to real temperature of steam (water)

at output from that run of pipes, for which is produced calculation of temperature of wall. For transition zones of single-passs boiler the temperature is accepted in the dependence on the state of medium in designed run of pipes: steam-water mixture or superheated steam.

During the calculation of output run of pipes this temperature takes as the equal to temperature of steam (water) at the output/yield. In the remaining cases it is calculated on the basis of the following indications.

The temperature of medium at the output from the first on the course of gases of run of pipes of the superheater (economizer), connected on the diagram of a consecutive-mixed current, is determined by the selection of the values of the heat absorption of the corresponding sections according to p. 7-67.

Upon the inclusion/connection of the heating surface on the diagram of an in parallel-mixed current the intermediate temperature of medium upon transfer of one course to another (i.e. in the first on the course of gases series/row) is designed from the indications p. 7-70.

The temperature heads for the separate courses of this superheater, designed as straight/direct or countercurrent, are

defined, as usual, under the condition of the constancy of the coefficient of heat transfer. The temperature of the gases before the heating surface is considered identical all over width of flue. For the calculation is accepted the value of temperature of steam (water) between the courses. By this value, known from the calculation of the entire heating surface final temperatures of steam and temperature of the gases before the flue is determined from the equation of balance the value of the temperature of gases after each course. After the calculation of the temperature heads for the separate courses the correctness of the value of intermediate temperature accepted steam is checked using formula (7-76).

Temperature of steam (water) for output from subsequent runs of pipes is designed with the help of determination of the total heat absorption of series/rows from the first to that designed inclusively. For this it is necessary to determine average/mean temperature pressure head in series/rows $\Delta t_p$ indicated. Its logarithm is calculated according to the formula

$$\lg \Delta t_p = \lg \Delta t' - \frac{H_p}{2H_{no.in}} (\lg \Delta t' - \lg \Delta t''). \quad (3)$$

$\Delta t'$ and $\Delta t''$ - the temperature heads upon the entrance into the heating surface and on the output from it, with °C; $H_p$ - surface of heating series/rows from the first to that checked inclusively, $m^2$; $H_{no.in}$ - surface of heating entire bundle in section), $m^2$.

By the calculated value of logarithm $\Delta t_p$ is determined the temperature head.

The heat absorption of the surface of heating series/rows from the first to that designed is found from the expression

$$Q_p = Q\frac{\Delta t_p}{\Delta t}\frac{H_p}{H_{полн}} \quad \text{kcal/kg,}$$

Q - the heat absorption of the entire surface of heating this flue or, with the consecutive (parallel) mixed current, the corresponding section, kcal/kg; Δt - average/mean temperature head in the bundle (section), °C.

4. Thermal load at point of maximum heat absorption of most loaded duct is located through average/mean value of thermal load at point of maximum thermal perception of ducts $q_0$ kcal/m² hour, to determined through paragraphs 7 and 8, and coefficient of nonuniformity of heat absorption through width (section/cut) $k_ш$. The latter is equal to the ratio of the heat absorption of the most loaded duct to the average along all ducts of the designed series/row (shield) and is accepted according to following data:

| | $k_ш$ |
|---|---|
| (1) Ряд конвективного пучка или ширмовая поверхность нагрева, занимающие всю ширину газохода . . . . . | 1,3 |
| (2) То же, занимающие среднюю часть газохода по ширине (до 2/3) или края газохода (до 1/4 ширины) . . . . . . | 1,2 |
| (3) Радиационная поверхность нагрева* . . | 1,4 |

$$q_{макс} = k_ш q_0 \quad \text{kcal/m}^2\text{h.} \qquad (4)$$

Key: (1). Series/row of convection bank or the screen heating surface, that occupy entire width of flue. (2). Then, that occupy middle part of flue in width (to 2/3) or edge of flue (to 1/4 widths). (3). Radiation surface of heating [1].

FOOTNOTE [1]. Coefficient considers full/total/complete nonuniformity of the distribution of thermal load according to the screen surfaces. ENDFOOTNOTE.

For the horizontal superheaters, placed in the horizontal flue (coils are arranged/located across the flue), nonuniformity in the width is not considered. Variation factor in the height of the flue before the refinement takes as the equal to 1.2.

5. Value of temperature excess of medium in most loaded duct above average $\Delta t_{m}$ °C depends on variation factor of heat absorption in width and heat absorption of bundle, for which is designed temperature of wall.

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It is defined as the difference

$$\Delta t_{m} = t_{макс} - t \text{ °C},$$

where t - calculated mean temperature of medium in that run of pipes,

for which is designed the temperature of wall, determined on p. 3, °C; $t_{макс}$ - temperature in the most warmed duct of the same series/row, which corresponds to the enthalpy of medium in this duct, °C; the latter is designed according to the formula

$$i'_{макс} = i + (k_{м} - 1)(i - i') \quad \text{kcal/kg}, \qquad (5)$$

i - the enthalpy of medium, which corresponds to temperature its t, in checked run of pipes, kcal/kg; i' - enthalpy of medium at the output from the collector/receptacle, connected (on the course of the heated medium) before row of pipes, for which is designed the temperature of wall, kcal/kg.

If the series-connected collector/receptacle it is intermediate and in it it is not ensured the full/total/complete mixing of the medium (there is no overflowing of medium along the collector/receptacle or its crossed transfer from the collector/receptacle to the collector/receptacle by a small quantity of overflow pipes) value $i_{макс}$ takes as the equal:

$$i_{макс} = i + (k_{м} - 1)(i - i') + 0{,}5(k_{м} - 1)(i' - i'_{пр}) \quad \text{kcal/kg} \qquad (5a)$$

$i'_{пр}$ - the enthalpy of medium at the entrance into the bundle, connected to this collector/receptacle, kcal/kg.

For the evaporative surfaces value $\mu_{w}$ is equal to zero.

6. Coefficient of spreading $\mu$ for ducts of first series/row nonfestooned convective superheaters ($s_1/d<3$) with checkered or corridor, by arrangement also of ducts of second series/row of festooned in checkered order superheaters is determined on Fig. 10a for ducts of all subsequent series/rows of superheaters - on Fig. 10b.

During the chamber combustion of schists for the ducts of the second series/row of feston superheater the spreading is not considered.

Here and subsequently presentation, when the beam in question is distant from previous (on the course of gases) for the value more than of two longitudinal pitches of the designed beam, the calculation of the series/rows of beam begins first. During the smaller removal/distance the calculation of series/rows is conducted from the first series/row of the previous beam.

For the ducts of the first series/row of semiradiation (screen) superheaters the spreading is not considered; for the ducts of all

subsequent series/rows the coefficient of spreading is determined on Fig. 11 along the line, which corresponds s/d=1.1.

For all ducts of radiation superheaters regardless of arrangement relative to tracking (e≥0) the coefficient of spreading is determined on the appropriate curves Fig. 11.

For the use of graphs/curves Figs. 10 and 11 it is necessary to preliminarily calculate value

$$b = \frac{d\alpha_2}{2\beta\lambda_m}.$$

7. Maximum heat absorption of radiation heating surface always occurs on frontal generatrix of duct. The average/mean value of thermal load on this generatrix takes as equal to [1]

$$q_0 = y\frac{B_pQ_s}{H_A}\ \text{kcal/m}^2\text{h}, \quad (6)$$

$\frac{B_pQ_s}{H_A}$ - the average thermal load of the beam-receiving surfaces, kcal/m² hour; y - variation factor of the distribution of thermal perception in the furnace chamber/camera (see Section 6-19).

FOOTNOTE [1]. With the shields, comprised of the ducts of different diameters, equality (6) is correct only for the ducts of larger diameter. For the ducts of smaller diameter into equality (6) should

be additionally introduced the value of the coefficient of the illumination (see Section 11). However, with the used in the boiler aggregates/units relationships/ratios of diameters and the steps/pitches value ¢ for frontal generatrix is close to the unit and can be disregarded. ENDFOOTNOTE.

In the presence in heating of the beam-receiving surfaces with the different values of the conditional coefficient of contamination ς the thermal load is determined from formula (6-25a).

8. In convection banks maximum of heat absorption falls in different series/rows to different points in circumference of duct. For the standard cases the location of maximum is accepted on Table 1.

For the screen heating surfaces are accepted the same data as for the corridor beams.

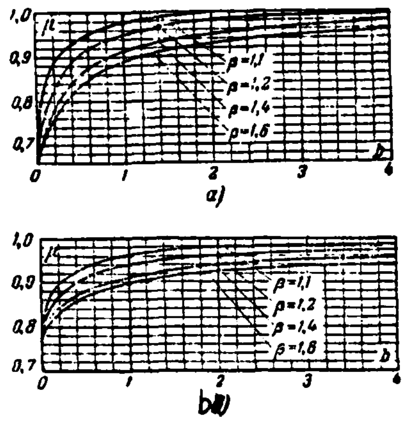


Fig. 10. Coefficient of spreading for the ducts of the convective heating surfaces. a) the duct of the first series/row of nonfestocned beam of corridor or checkered) and the second series/row of the festooned checkered beam; b) the duct of any third (or of that following) series/row of checkered and corridor beams.

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The average/mean value of the thermal load of duct at the point of maximum thermal perception is determined from formula (7)

$$q_0 = \frac{\vartheta_p - t}{\mu\left(\frac{\delta}{\lambda_м}\frac{2}{\beta+1} + \frac{1}{\alpha_к+\alpha_л} + \varepsilon\right)} \quad \text{kcal/m}^2 \quad \text{hour} \quad (7)$$

$\vartheta_p$ - the temperature of gases at the entrance into that series/row, for which is designed temperature of wall, °C; value $\vartheta_p$ is determined either from the heat balance by the calculated value of the

temperature of medium t or by the prescribed/assigned final temperatures of gases according to indications p. 3; $\varepsilon$ - contamination factor of the designed section:

$$\varepsilon = 0{,}25\varepsilon_{cp}$$ m² hour deg/kcal, (8)

where $\varepsilon_{cp}$ - average/mean value of contamination factor for this heating surface, determined during its thermal design, m² hour deg/kcal.

Other designations - the same as in formula (1).

9. Convection heat-transfer coefficient $\alpha_{к}$ kcal/m² hour deg is determined from equality

$$\alpha_{к} = k_{mp}\alpha_{к.cp}$$ kcal/m² hour deg, (9)

$k_{mp}$ - variation factor in circumference of duct whose value is accepted on Table 1 in dependence on shape of beam and number of series/row; $\alpha_{к.cp}$ - average/mean in circumference of duct value of convection heat-transfer coefficient, kcal/m² hour deg ; it is determined on nomogram II or by III in depending on beam shape; in this case correction for number of series/row $C_z'$ (introduced instead of correction for to number of series/rows $C_z$) is accepted taking into

account preliminary agitation of flow:

for ducts of first series/row - in value $C_z$ for double-row beam;

for the ducts of the second series/row - in value $C_z$ for the four-row beam;

for the ducts third and subsequent series/rows $C_z'=1$.

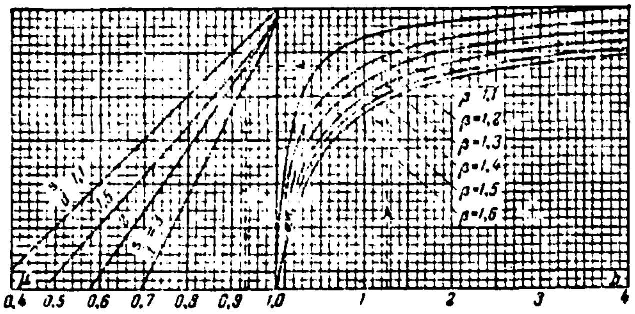


Fig. 11. Coefficient of flow spread for screen ducts (e≥0).

Table 1.

| (1) № ряда | (2) Коридорный пучок | | (3) Шахматный пучок | |
|---|---|---|---|---|
| | (4) Угол между лобовой точкой и точкой с максимальным тепловосприятием, град. | (5) Коэффициент неравномерности по окружности трубы $\kappa_{mp}$ | (4) Угол между лобовой точкой и точкой с максимальным тепловосприятием, град. | (5) Коэффициент неравномерности по окружности трубы $\kappa_{mp}$ |
| I | 0 | 1,6 | 0 | 1,6 |
| II | 60 | 1,7 | 0 | 1,7 |
| III | 60 | 1,5 | 0 | 1,5 |
| (6) IV и последующие | 60 | 1,4 | 0 | 1,6 |
| (7) Последний ряд пучка при наличии газового объема за пучком | 180 | 1,0 | $\frac{180}{0^{*1}}$ | $\frac{1,0}{1,6}$ |

Key: (1). series/row. (2). Corridor beam. (3). Checkered beam. (4). Angle between front point and point with maximum heat absorption, deg. (5). Variation factor in circumference of duct. (6). IV and following. (7). Latter/last series/row of beam in presence of gas volume after beam.

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FOOTNOTE [1]. With the high-ash fuels/propellants (schists) the maximum always at point of 180°; with without ash-bearings fuel (gas, layer combustion) - at point of 0°. In the remaining cases should be checked values of $q_0$ for both limit points. ENDFOOTNOTE.

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The temperature of flow takes as equal to $\theta$,°C. Gas velocity is designed from this temperature, clear opening of the series/row, for

which is determined the temperature of wall, and to the average/mean for this flue volume of combustion products.

10. Radiation heat-transfer coefficient $\alpha_{л}$, kcal/m² hour deg is determined in depending on number of run of pipes in beam.

For the ducts of the first series/row of all beams the heat-transfer coefficient $\alpha_{л}$ is designed from the cavity emission, arranged/located before the beam.

The efficient thickness of radiation layer during the calculation of the radiation/emission of volume to the beams, which occupy entire width of flue or its middle part, is determined from the formula

$$s=\frac{2.2}{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}}\ м, \qquad (10)$$

where a, b and c - average/mean values of height, width and depth of gas volume, m.

For the beams, arranged/located on the edges of flue and occupying not more than its 1/4 width, and also for the ducts, arranged/located on the end walls, numerator in formula (10) takes as the equal to 1.8.

By the calculated thickness of radiation layer, the average/mean

for this beam values of the volume fractions of triatomic gases and concentration of ash, the temperature of the gases before the beam and the value of the temperature of the contaminated wall accepted is determined in nomograms the IX-XI value of radiation heat-transfer coefficient $\alpha_{л}$ substituted in equation (7). Value $t_з$ should be preliminarily assigned and after determination of $q_0$ calculate according to formula (2) $t''_{cm}$ and tested value $t_з$ accepted on the equality

$$t_з = t''_{cm} + \varepsilon q_0 \,°C.$$

Value $t_з$ is made more precise only when determined value differs from that accepted more than by 50°C.

If gas volume is isolated from the heating by beam or scallop with a number of runs of pipes (on the course of gases) not more than four, should be considered the heat, which falls to the checked ducts from the heating. In this case the total quantity of radiation heat-transfer coefficient of volume and heating is calculated in the formula

$$\alpha_{л.об+т} = \alpha_{л.об} + y\frac{B_p Q_л}{H_л}\frac{1 - x_{пуч}}{\theta' - t_з}(1 - a_{об}) \text{ kcal/m}^2 \text{ hour deg}, \quad (11)$$

$\alpha_{л.об}$ - radiation heat-transfer coefficient of volume, kcal/m² hour deg; $a_{об}$ - emissivity factor of volume, determined during the calculation of value $\alpha_{л.об}$ according to the auxiliary field of nomogram

XI; $y\frac{B_p Q_4}{H_4}$ - thermal load of the beam-receiving surfaces in the zone of the output window of the heating (see Section 6-19), kcal/m² hour: $x_{nyu}$ - angular coefficient of the beam, arranged/located between the heating and the volume, determined by RN 6-02.

If superheater is isolated from the heating by beam or scallop with five and more by runs of pipes, radiation/emission from the heating is not considered.

11. For ducts of second series/row of corridor beam, from second on sixth series/row that rarefied ($s_1/d \geq 4$) and from second in fourth series/row that not rarefied of checkered beams ($s_1/d \leq 2.5$) radiation heat-transfer coefficient is calculated taking into account angle of vision to gas volume before beam.

The coefficient of illumination for the point with the maximum heat absorption is determined by graphic construction (Fig. 12). For this:

a) on the arbitrary scale are drawn the checked duct and ducts in front of the lying/horizontal series/rows (along three ducts in the series/row on the one hand of that checked);

b) from point O with the maximum of heat absorption on the

checked duct (see Table 1) is carried out the semicircumference, limited by diameter ~~AV~~ AB, by tangent to the circumference of duct at the point indicated;

c) from point O are conducted rays/beams, tangents to the ducts in front of the lying/horizontal series/rows; these rays/beams must not intersect one in front of the lying/horizontal duct;

d) the sections of the arc of semicircumference, included between two adjacent rays/beams, which limit free from the ducts space, are projected/designed for diameter AB.

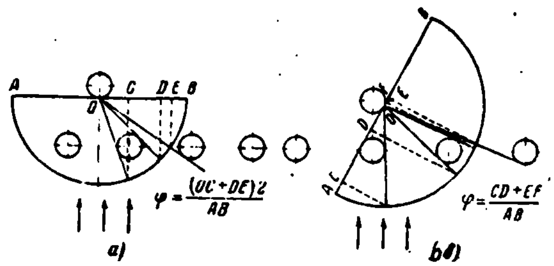


Fig. 12. Construction of the coefficients of illumination. a) the coefficient of illumination for the duct of the second series/row of checkered beam (face girding); b) the coefficient of illumination for the duct of the second series/row of corridor beam (point, misaligned from the frontal by 60°).

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e) the coefficient of illumination for point O is equal to the ratio of the sum of the projections of the sections indicated to the length of diameter.

Radiation heat-transfer coefficient

$$\alpha_{л} = \varphi_{об}\alpha_{л.об+m} + (1-\varphi_{об})\alpha_{л.нм} \quad \text{kcal/m}^2 \text{ hour deg.} \qquad (12)$$

Radiation heat-transfer coefficient of volume and heating $\alpha_{л.об+m}$ is determined from formula (11).

For determining the heat-transfer coefficient with intertube radiation/emission $\alpha_{л.мт}$ the thickness of radiation layer they calculate according to formula (7-48) or (7-49) on actual spacings between tubes in the checked section; the temperature of gases accept equal to $\vartheta_{p}$ and remaining values - on the indications p. 10.

12. For ducts of series/rows, arranged/located afterward indicated into p. 11, radiation heat-transfer coefficient it is determined only on between pipe radiation/emission in accordance with indications p. 11.

13. For ducts of latter/last series/row of beam after which is arranged/located gas volume by depth not less than three longitudinal pitches of beam, radiation heat-transfer coefficient for point, misaligned by 180° from frontal, is determined on radiation/emission of this volume. The value of the heat-transfer coefficient of volume is calculated according to indications p. 10; the temperature of gases takes as the equal to temperature after the beam.

The coefficient of heat transfer for the face grinding of the duct of latter/last series/row is calculated according to the indications p. 12.

14. For ducts of first series/row of screen heating surfaces radiation heat-transfer coefficient

$$\alpha_{л} = y \frac{B_p Q_л}{H_л} \frac{1}{\vartheta' - t_з}$$ kcal/m² hour deg. (13)

Designations the same as in formulas (10) and (11).

For the ducts of the subsequent series/rows

$$\alpha_{л} = \varphi_m y \frac{B_p Q_л}{H_л} \frac{1}{\vartheta_p - t_з} + (1 - \varphi_m) \alpha_{л.об}$$ kcal/m² hour deg, (14)

where $\varphi_m$ - coefficient of the illumination of point with the maximum of heat absorption from the heating, determined in the indications p. 11; for the ducts of the second - the fifth of series/rows it is accepted $\varphi_m = 0{,}5$; $\vartheta_p$ - calculated temperature of gases in this series/row, °C; $\alpha_{л.об}$ - radiation heat-transfer coefficient of the volume between the screens with the temperature of gases $\vartheta_p$ °C and the efficient thickness of radiation layer, the specific according to formula (8-11) kcal/m² hour deg.

15. Heat-transfer coefficient from wall to internal medium $\alpha_2$ kcal/m² hour deg for superheater is determined on nomogram V. All

initial values for determining the heat-transfer coefficient are accepted according to the calculated temperature of steam $t_{макс}$ (see p. 5) in that duct, for which is checked the temperature of wall. Pressure of steam takes as the equal: for the initial sections - to pressure in the drum, for the final ones - to pressure after the steam cutoff catch, for the intermediate ones - to average between these values.

For the evaporative surfaces the coefficient of heat transfer is determined with the oxidizing ducts on nomogram XXVI, and with the high-alloy noncorrosive ducts - according to formula (7a) of Appendix III. For determining $\alpha_2$ preliminarily should be taken value value $\alpha_2$ it is designed again only in such a case, when taken and calculated values $q_{макс}$ they are separated to more than 10o/o.

16. When pressure differential in distributing and assembling collectors/receptacles of bundle of superheater commensurable with resistance of ducts, which connect collectors/receptacles, that most frequently can occur with three-coil superheaters, large diameter of coils and at comparatively small length of ducts between collectors/receptacles, for example, in radiation superheaters, especially at reduced pressure of steam in boiler, should be calculated hydraulic nonuniformity of distribution of steam on the basis of coils.

The value of nonuniformity, other conditions being equal, depends on the connection of collectors/receptacles. By the greatest nonuniformity is characterized diagram Z (Fig. 13), smaller have diagram II and diagram H, which is the dual diagram P. With any quantity of supplying and outlet pipes collector system can be represented in the form of several systems, connected on the simplest diagrams indicated. Diagram with the supply and the diversion/tap of pair by a large quantity or ducts is characterized by virtually completely uniform steam supply and does not require testing.

Degree of irregularity is characterized by the value of the ratio of minimum expenditure/consumption on the coil to the average:

$$\eta = \frac{g_{мин}}{g_{cp}} \qquad (15)$$

and it is calculated according to the formulas:

for diagram Z

$$\eta_z = \frac{2}{1+\sqrt{\dfrac{\delta p + \Delta p_c + \Delta p_p}{\delta p}}}; \qquad (16)$$

for the diagram P, if a change of the pressure in the assembling collector/receptacle is more than in that distributing,

$$\eta_n = \frac{2}{1+\sqrt{\dfrac{\delta p + \Delta p_c}{\delta p + \Delta p_p}}}; \qquad (17)$$

then, if a change of the pressure in the distributing collector/receptacle is more than in that assembling,

$$\eta_n = \frac{2}{1+\sqrt{\dfrac{\delta p + \Delta p_p}{\delta p + \Delta p_c}}}. \qquad (18)$$

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Diagram H they conditionally divide/mark off into two halves (Fig. 13) and each designs as diagram P. So they enter the cases of more compound circuits.

In the latter/last formulas: δp - full/total/complete calculated loss of pressure in the coil of bundle, calculated according to the common formulas, kg/m²; $\Delta p_c$ - pressure drop in the assembling collector/receptacle, kg/m², determined according to the formula [1]

$$\Delta p_c = 2{,}5 \frac{w''^2}{2g} \gamma_c \quad \text{kg/m}^2, \qquad (19)$$

w" - the speed of steam in the section/cut of collector/receptacle after the latter/last duct, m/s; $\gamma_c$ - specific gravity/weight of steam in the assembling collector/receptacle, kg/m³; $\Delta p_p$ - lift of pressure in the distributing collector/receptacle, kg/m², determined according to the formula [2]

$$\Delta p_p = C_1 \frac{w'^2}{2g} \gamma_p \quad \text{kg/m}^2; \qquad (20)$$

w' - the speed of steam in the section/cut the collector/receptacle

before the first duct, m/s; $\gamma_{\text{п}}$ - specific gravity/weight of steam in the distributing collector/receptacle, kg/m³.

FOOTNOTE [1]. If in the initial section/cut of collector/receptacle speed $w'=0$, into the numerator of formula (19) is substituted value $w''^2-w'^2$.

[2]. If in final section/cut of collector/receptacle speed $w'' \neq 0$, into numerator of formula (20) is substituted value $w'^2-w''^2$. ENDFOOTNOTE.

Coefficient $C_1$ takes as the equal to: 0.82 - during the end supply by the total cross section of collector/receptacle, $2\left(\frac{F_{\text{вх}}}{F_{\text{км}}}-0{,}59\right)$ - during the end supply by branch with the diameter smaller than the diameter of collector/receptacle, and 0.96 - during the side supply (Fig. 13).

Enthalpy of steam at the output from the coil with the minimum expenditure/consumption is designed taking into account determined degree of irregularity:

$$i_\eta = i' + \frac{i - i'}{\eta} \quad \text{kcal/kg.} \qquad (21)$$

Designations in this formula see formulas (5) and (15).

Since the nonuniformity of heat absorption in the width, considered on the indications p. 5, leads usually to an increase in the temperature of steam in the average/mean in the width of flue coils, the combined effect of thermal and hydraulic nonuniformity should be considered when in the bundle, which occupies entire width of flue, coils with the minimum expenditure/consumption of steam are placed in its middle part. In these cases into formula (5) instead of value i is substituted value $i_k$. In the remaining calculation of the temperature of wall it remains without the changes.

Minimum expenditure/consumption of steam corresponds to the coils, connected between those sections/cuts of the collectors/receptacles, for which pressure difference in the distributing and assembling collectors/receptacles is smallest. The location of these sections/cuts is determined in accordance with the diagrams/curves of the distribution of pressures along the collectors/receptacles, given in Fig. 13.

During the arrangement/position of coils with the minimum expenditure/consumption on the edges of flue (at the removal/distance from the walls to 1/6 widths) is considered only that form of nonuniformity, which causes a larger increase in the temperature of wall. As a rule, should be calculated only the nonuniformity of heat absorption on the basis of the width and conducted calculation,

disregarding hydraulic nonuniformity.

With a noticeable difference in the configurations of the in parallel connected coils due to their different resistances appears the additional nonuniformity, not considered in the calculation procedure in question. This additional nonuniformity must be introduced into the calculation, if the specific resistances of the in parallel connected coils are distinguished between themselves to 10c/o or more.

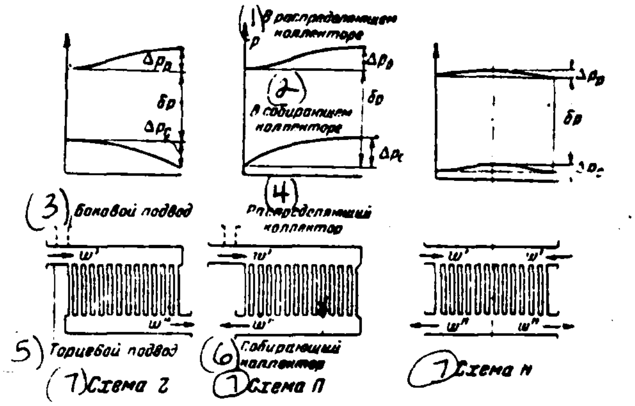

Fig. 13. Connections of collecters/receptacles and curves of pressures.

Key: (1). In the distributing collector/receptacle. (2). In assembling collector/receptacle. (3). Side supply. (4). Distributing collector/receptacle. (5). End supply. (6). Assembling collector/receptacle. (7). Diagram.

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Appendix V

BRIEF INDICATIONS IN ACCORDANCE WITH THE DESIGN/PROJECTION OF COMBUSTION SYSTEMS AND HEATING SURFACES.

Present recommendations relate to the design/projection of combustion systems and surfaces of heating stationary boiler aggregates/units with the water-tube boilers, in essence with the gravity circulation. Partially these recommendations can be used also for other types of boiler aggregates/units.

Recommendations regarding the design/projection contain guiding indications for the designers and designers, but they are not norms and their fulfillment is not compulsory.

A. Combustion systems.

a) General considerations.

1. Selection of combustion system is determined by physicochemical properties of fuel/propellant, by steaming capacity

and construction/design of boiler aggregate/unit.

Chamber furnaces for combusting the fuel/propellant in the powdered and suspension can be used, as a rule, under the ball solid fuels, with exception of lump peat, firewood and wood withdrawals/departures.

Table 1. Recommended types of chamber furnaces.

| (1) Топливо | (2) Паропроизводительность котла, т/час | (3) Тип топочного устройства | |
|---|---|---|---|
| | | (4) рекомендуемый | (5) заменяющий |
| (6) Антрацитовый штыб . . | $\geqslant 35$ | (7) Пылеугольная топка[1] | — |
| (8) Тощие угли . . . . . . | $\geqslant 12$ | (7) Пылеугольная топка[1] | — |
| (9) Каменные угли, $V^г < 30\%$ | $\geqslant 12$ | (7) Пылеугольная топка | — |
| (9) Каменные угли, $V^г \geqslant 30\%$ | $\geqslant 12$ | (7) Пылеугольная топка | (10) Шахтно-мельничная топка[2] |
| (11) Отходы углеобогащения[3] . . . . . . . . . | $\geqslant 12$ | (7) Пылеугольная топка | (7) — |
| (12) Бурые угли, $W^п \leqslant 15$ . . | $\geqslant 12$ | (13) Шахтно-мельничная топка | Пылеугольная топка |
| (12) Бурые угли, $W^п = 15 \div 30$ | $\leqslant 6{,}5$ | (14) Пневматическая топка ЦКТИ системы Шершнева[4] | — |
| (15) То же . . . . . . . . . | $> 12$ | (16) Топки с мелющими вентиляторами | Шахтно-мельничная (17) топка[5] |
| (12) Бурые угли $W^п = 20 \div 30$ | $> 35$ | (18) Пылеугольная топка[6] | Шахтно-мельничная (19) топка[7] |
| (12) Бурые угли, $W^п > 30$ . . | $\geqslant 12$ | (18) Пылеугольная топка[6] | Шахтно-мельничная (19) топка[7] |
| (21) Сланцы . . . . . . . . | $\geqslant 12$ | (13) Шахтно-мельничная топка | Пылеугольная топка (7) |
| (22) Фрезерный торф . . . . | $< 4$ | Вихревые топки (24) | — |
| (15) То же . . . . . . . . . | $4 \div 20$ | (20) Пневматическая топка ЦКТИ системы Шершнева[8] | Шахтно-мельничная топка (19) |
| (15) То же . . . . . . . . . | $> 20 \div 75$ | (13) Шахтно-мельничная топка | (20) Пневматическая топка ЦКТИ системы Шершнева[8] |
| (15) То же . . . . . . . . . | (23) $> 75$ | (13) Шахтно-мельничная топка | — |
| Мазут и газ . . . . . . | Нет ограничений | Камерная топка (25) | — |

Note.

Under the coal-dust heatings are understood the heatings, equipped by coal-dust burners, including with the grinding of fuel/propellant in the unit type mills. mine-mill are named the heatings, supplied with the open embrasures or to embrasures with different dividers , etc.

Key: (1). Fuel/propellant. (2). steam capacity of boiler, m/h. (2). Boiler steam capacity, m/h. (3). Type of combustion system. (4). recommended. (5). substituting. (6). Anthracite fines. (7). Pulverized-coal combustor [1].

FOOTNOTE [1]. For ASh and lean coal with the boiler steam capacity is above 35 m/h is recommended the supply to dust into the heating by hot air. ENDFOOTNOTE.

(8). Lean coal. (9). Bituminous coal. (10). mine- mill furnace[2].

FOOTNOTE [2]. It is adapted when $k_{\Lambda O} \geq 1.2$. With D>35 m/h are adapted coal-dust burners. ENDFOOTNOTE.

(11). By-product coal [3].

FOOTNOTE [3]. For the withdrawals/departures of enrichment, with $V_{r} \geq 30\%$, $k_{\Lambda O} \geq 1.2$ and the boiler steam capacity to 35 m/h, sometimes is allowed/assumed the use/application of mine-mill heatings.

FOOTNOTE (12). Brown coal. (13). Mine- mill heating. (14). Pneumatic heating of TsKTI system of Shershnev. [4].

FOOTNOTE [4]. It is recommended for the earthen brown coal with WP<52o/o. Must be provided for the preliminary splitting of carbon/coal to the on-screen residue 5x5 not more than 5o/o. ENDFOOTNOTE.

(15). Then. (16). Heatings with grinding fans. (17). Mine-mill furnace[5].

FOOTNOTE [5]. With the preliminary drying (to the grinding) on the locked or extended diagram. ENDFOOTNOTE.

(18). Pulverized-coal combustor [6].

FOOTNOTE [6]. With the extended diagram of pulverized coal preparation. ENDFOOTNOTE.

(19). mine- mill heating [7].

FOOTNOTE [7]. With the preliminary drying (to the grinding) on the extended diagram. ENDFOOTNOTE.

(20). Pneumatic heating of TsKTI system of Shershnev. [8].

FOOTNOTE [8]. It is adapted in the absence of the need for work on the substitutes of cut peat. ENDFOOTNOTE.

(21). Schists. (22). Milling peat. (23). There are no limitations. (24) Swirl furnaces; (25) Chamber furnace.

FOOTNOTE [9]. Sometimes is allowed/assumed use for boilers D=20 m/h. ENDFOOTNOTE.

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The joint combustion of powdered fuel with the blast-furnace gas is not recommended as a result of the significant growth of furnace losses.

Concrete/specific/actual indications about the selection of chamber furnaces in depending on the form of fuel/propellant and steaming capacity of boiler aggregate/unit are given in Table 1.

2. Layer heatings for run-of-the-mine coal, as a rule, it is expedient to use under boilers by steaming capacity to 20 m/h. Sometimes layer combustion can prove to be of expedient and for the boilers larger steaming capacity.

The heatings with chain/circuit lattices/grids, equipped by precombustion chambers, can be used for combusting the lump peat under the boilers by steaming capacity to 230 m/h.

Layer heatings do not ensure the satisfactory combustion of the anthracite fines, emaciated noncaking and high-moisture brown (W" ≥ 15) carbon/coals, milling peat and fine/small production wastes (husk, sawdust, etc.); therefore for these fuels/propellants they are not recommended.

Concrete/specific/actual indications about the selection of layer heatings in depending on the form of fuel/propellant and steaming capacity of boiler aggregate/unit are given in Table 12.

3. When selecting of type of heatings for boilers by steaming capacity below 20 m/h should be considered need for most complete mechanization of all processes. In connection with this the use/application of heatings with the manual maintenance/servicing can be permitted only for the boilers by steaming capacity to 1 and only the substances in individual cases to 2 m/h.

b) Heatings for the chamber combustion.

4. Selection of type of chamber furnace in depending on form of burned fuel/propellant and steaming capacities of boiler assemlby is recommended to produce according to data of Table 1.

5. During calculation of furnace chambers/cameras with dry and

liquid slag disposal temperatures of gases at output/yield from heating start from conditions of warning/preventing slag formation on Table 2. These temperatures are assigned for those cases when the following after the heating convective surfaces have the rarefied part (for example, festoon and rarefied first runs of pipes of superheater), which reduces the temperature of gases not less than on 50°C.

The screens with two tiers of windows and the screen heating surfaces can be arranged/located in the zone of the temperatures, which exceed those indicated by Table 2; the distances between the screens must be with this not less than 700 mm.

6. For carbon/coals, shown in Table 2, temperature of gases at output from heating tentatively can be taken as equal to temperature of beginning of deformation/strain of ashes (see pH 2-01) but not more than 1150°C.

7. Quantity of burners in depending on type and their location is recommended to select in accordance with data, given in Table 3.

8. As circular turbulent burners are recommended burners of type of ORGRES [ ОРГРЭС - State Trust for the Organization and Rationalization of Regional Electric Power Plants and Networks] or

TKZ.

During the angular locaticn are reccmmended slit type burners. Slit burners is expedient tc carry out by rctary cnes [1] for the possibility of flame ccntrol in the heating.

FOOTNOTE [1]. Besides ASh and carbonaceous coal. ENDFOOTNOTE.

During the angular lccation of burners the relationship/ratio of the sizes/dimensicns of heating in the plan/laycut is desirably nct more than 1-1.2.

As the outflow burners are recommended the burners in the form of the nozzles of rectangular cross section with the location of the larger side of burner cn the height of heating.

9. Selection of distances between burners, and also from burners to enclosing surfaces fcllows it produces in accordance with data, given in Table 4.

During two-next the locaticn cf burner it should be placed on the triangle by apex/vertex upward for the frcnt or dcwnward for the lateral - counter locaticn.

Table 2. Maximum permissiole the temperatures of gases according to the conditions of slag tuiidup.

| (1) Топливо | D<200 т/час (2) | D≥200 т/час (2) |
|---|---|---|
| (3) Антрацитовый штыб | 1 150 | 1 100 |
| (4) Тощие угли | | |
| (5) Донецкий | 1 100 | 1 050 |
| (6) Араличевский | 1 150 | 1 100 |
| (7) Каменные угли | | |
| (8) Карагандинский | 1 150 | 1 100 |
| (9) Кемеровский | 1 100 | 1 050 |
| (10) Кизеловский | 1 100 | 1 050 |
| (11) Воркутский | 1 100 | 1 050 |
| (12) Отходы углеобогащения | | |
| (13) Донецкий ППМ | 1 100 | 1 050 |
| (14) Бурые угли | | |
| (15) Подмосковный | 1 100 | 1 050 |
| (16) Челябинский | 1 100 | 1 050 |
| (17) Богословский | 1 150 | 1 100 |
| (18) Сланцы | | |
| (19) Эстонские и гдовские | 900 | 850 |
| (20) Волжские | 950 | 900 |
| (21) Торф | | |
| (22) Фрезерный торф | 1 000 | 950 |

Note. For the bcilers by steaming capacity not above 120 m/h with the difficulty cf cooling gases by wall screens down to the indicated in Table 2 values of the maximum permissible temperature is allowed/assumed an increase in the temperature cf gases at the output from the heating against the values, indicated in Table 2, but not higher than on 50°C.

Key: (1). Fuel. (2). m/h. (3). Anthracitic coal dust. (4). Lean coal. (5). Donets. (6). Aral. (7). Bituminous coal. (8). Karaganda. (9). Kemerovo. (10). Kizelovskiy. (11). Vorkutskiy. (12). By-product coal.

(13). Donets PPM. (14). Brown coal. (15). Moscow. (16). Chelyabinsk. (17). Theological. (18). Schists. (19). Estonian and Gvodskiy. (20). Volga. (21). Peat. (22). Milling peat.

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During the location of burners on the triangle the distance between the adjacent burners on the horizontal is received as 2-3.2 m when $D_{t}<25$ m/h and 3-4 m when $D_{t}>25\div40$ m/h.

10. Length of flame[1] should be selected not less: for boilers by steaming capacity 20-50 m/h of 7-10 m; for boilers by steaming capacity 75-120 m/h of 11-13 m; for boilers by steaming capacity 150-230 m/h of 14-16 m.

FOOTNOTE [1]. Under the length of torch is understood its conditional trajectory, planned along the axis of burners from their mouth to the vertical axis of heating, then along the vertical axis - from the plane of the location of burners to middle of boiler beam, or festoon and - with the lateral yield of gases - from the vertical axis to the encounter with the tube bank. With layer firing the calculation is conducted from the axes of the upper row of burners. ENDFOOTNOTE.

The upper limits are recommended for ASh and lean coal.

11. Furnace depth during front location of burners or embrasures should be selected in accordance with data of Table 5.

12. Exit velocities of dusty mixture and second and outflow air from burners are selected for rated steam capacity of boiler in accordance with data of Table 6.

13. Selection of speeds in embrasures and nozzles of mine-mill heatings is recommended to produce according to data of Table 7.

14. Embrasures of mine-mill heatings one should to establish as near as possible to cold funnal, leaving on front wall under embrasures only place for distribution of lower nozzles. Minimum distance from the lateral face of extreme embrasures to the adjacent walls must be not less than 400 mm.

With the open embrasures the angle of the slope of upper nozzles to the horizon is recommended with 45-55°, and lower of -25-35°.

Table 3. Quantity cf dust burrers.

| (1) Паропроизводительность котла, т/час | (2) Расположение и тип горелок | | | | |
|---|---|---|---|---|---|
| | (3) фронтовое | | (4) боковое — встречное | | (5) угловое |
| | (6) круглые турбулентные | (7) многощелевые[1] | (6) круглые турбулентные | (7) многощелевые[1] | (8) щелевые |
| (9) До 50[2] | 2÷3 | — | — | — | — |
| 75÷120 | 3÷4 | 4 | 4÷6 | — | 4÷8 |
| 150÷230 | — | 4÷6 | 6 | 6 | 8 |

Key: (1). Boiler steam capacity, m/h. (2). Iccation and type cf turners. (3). frcnt. (4). lateral - ccunter. (5). angular. (6). circular turbulent. (7). multislot [1].

FOOTNOTE [1]. They are adapted scmetimes fcr ccmbusting rock and brown coal. ENDFOOTNOTE.

(8). slit. (9) To.

FOOTNOTE [2]. During the installaticn of two turners one shculd establish/install the third reserve feeder cf dust with the chutes to both pulverized coal ccnduits.

Table 4. Arrangement/pcsiticr cf burners in the pulverized-ccal combustors.

| | (1) Раз-мер-ность* | (2) Условная производительность горелки по пару, т/час | | | |
|---|---|---|---|---|---|
| | | < 25 | >25÷50 | <25 | >25÷50 |
| | | (3) круглые турбулентные при фронтовом или встречном расположении | | (4) щелевые при угловом расположении | |
| (5) Расстояние от оси нижнего ряда горелок до верха холодной воронки [1] | м | 1,5÷1,7 | 1,7÷2,2 | 1,2÷1,4 | 1,4÷1,6 |
| (6) Расстояние от осей крайних горелок до примыкающих стен | • | 1,5÷1,8 | 1,8÷2,2 | — | — |
| (7) Расстояние между осями смежных горелок по горизонтали и между рядами горелок по вертикали | • | 1,6÷2,0 | 2,0÷2,5 | 1,4÷1,6 | 1,6÷1,8 |

Key: (1). Dimensionality. (2). Conditional productivity of burner on steam, m/h. (3). circular turbulent during front or counter location. (4). slit during angular location. (5). Distance from axis of lower row of burners to top of cold funnel [1].

FOOTNOTE [1]. During the location of burners on the triangle by apex/vertex downward the distance is received as 0.7-1.2 m; with location by the apex/vertex upward 1.2-1.5 m for the burners by productivity $D_r < 25$ m/h and 1.4-2 m for $D_r > 25$ 40 m/h on steam. ENDFOOTNOTE.

(6). Distance from axes of extreme burners to adjacent walls. (7). Distance between centers of adjacent burners on horizontal and between rows of burners on vertical line.

Table 5. Furnace depth.

| | | | | | |
|---|---|---|---|---|---|
| (1) Паропроизводительность котельного агрегата, *т/час* | 12 | 20 | 75 | 120 | 230 |
| (2) Рекомендуемая глубина топки не менее, *м* | 4,0 | 4,5 | 5,5 | 6,0 | 7,0 |

Key: (1). Steaming capacity of boiler aggregate/unit, m/h. (2). Recommended furnace depth is not less, m.

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Nozzles on the rear furnace wall should be arranged/located at the level of embrasures horizontally or with the inclination/slope downward to 15°.

The use/application of the open embrasures in the shaft-mill furnace ensures the sufficiently effective combustion of brown coal and milling peat under the boilers of small and average/mean power. For the boilers of large power, and also during the combustion of bituminous coal for the purpose of an increase in efficiency/cost-effectiveness and improvement of the adjustability of burning process is recommended the use/application of special burner devices/equipment.

15. To speed in burners for blast-furnace gas it should be selected according to data of Table 8, and for flameless burners -

according to data of Table 9.

16. Oil sprayers for constant combustion of petroleum residue must, as a rule, be used with mechanical atomization/pulverization. For the boilers of small steaming capacity (to 20 m/h) are allowed/assumed the sprayers with the steam atomization/pulverization of petroleum residue. Expenditure of steam for atomization/pulverization is 0.3-0.35 kg/kg.

17. To air speed in mazut and gas burners it should be selected according to data of Table 10.

Outlet gas velocity from the slots of gas and gas-oil burners starts within the limits of 25-150 m/s in depending on the available gas pressure.

Table 6. Speeds of primary, seccnd and outflow air on leaving from the burners into the heating, m/s.

| (1) Тип горелок | (2) Антрацитовый штыб | | (3) Тощие угли | | (4) Каменные и бурые угли | |
|---|---|---|---|---|---|---|
| | (5) Первичный | (6) Вторичный | (5) Первичный | (6) Вторичный | (5) Первичный | (6) Вторичный |
| (7) Круглые турбулентные ТКЗ (улиточного типа) или ОРГРЭС | 12÷16 | 18÷22 | 16÷20 | 20÷25 | 20÷26 | 20÷30 |
| (8) Щелевые горелки при угловом расположении | 27÷32 | 27÷32 | 27÷32 | 27÷32 | 27÷3? | 32÷37 |
| (9) Сбросные горелки | 30÷40 | — | 30÷40 | — | 30÷40 | — |

Key: (1). Type of burners. (2). Anthracitic. (3). Lean coal. (4). rock and brown coal. (5). Primary. (6). Seccnd. (7). Circular turbulent TKZ (spiral type) cr CRGRES. (8). Slit burners during angular location. (9). Cutflcw burners.

Table 7. Exit velocities of air mixture and air in shaft-mill furnace m/s.

| (1) Типы амбразур и сопел | (2) Пылевоздушная смесь | | (3) Сопла над и под амбразурами | (4) Сопла эжекционных амбразур | | (5) Сопла на задней стене топки | (6) Устье холодной воронки |
|---|---|---|---|---|---|---|---|
| | (7) Фронтовое расположение амбразур | (8) Угловое расположение амбразур | | (9) верхние | (10) нижние | | |
| (11) Полые амбразуры и амбразуры с горизонтальными рассекателями | 4÷6 | — | 20÷40 | — | — | 35÷-45 | 5÷6 |
| (12) Эжекционные амбразуры ЦКТИ | 4÷6 | — | — | 15÷20 | 25÷30 | 35÷45 | — |
| (13) Амбразуры с соплами в виде вертикальных щелей | — | 15÷18 | — | 30÷35 | 30÷35 | — | 5÷6 |

Notes.

1. Upper limits relate to boilers of larger steaming capacity.

2. Downdraft through mouth of cold funnel is adapted only during combustion of milling peat. A quantity of air, applied in the mouth, must compose 10-15o/o of the quantity of air, supplied to the heating.

Key: (1). The types of embrasures at puffed. (2). Dusty mixture. (3). Nozzles above and under embrasures. (4). Nozzles of ejecting embrasures. (5). Nozzles on rear wall of heating. (6). Mouth of cold funnel. (7). Front location of embrasures. (8). Angular location of embrasures. (9). upper (10). lower. (11). Hollow embrasures and embrasures with horizontal by breakwaters. (12). Ejecting embrasures of TsKTI. (13). Embrasures with nozzles in the form of vertical slots.

Table 8. Air speeds and tlast-turnace gas in the burners.

| (1) Тип горелки | (2) Скорость воздуха на выходе из щелей горелки, м/сек | (3) Скорость доменного газа на выходе из щелей горелки, м/сек |
|---|---|---|
| (4) Угловые горелки ЛМЗ . . . . . | 35÷45 | 30÷35 |
| (5) Щелевые горелки | 20÷30 | 20÷30 |
| (6) Трубчатые горелки . . . . . | 25 | 25 |

Key: (1). Type of burner. (2). Air speed at output from slots of burner, m/s. (3). Speed of blast-furnace gas at output from slots of burner, m/s. (4). Tangential burners of LMZ. (5). Slit burners. (6). Tubular burners.

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18. During arrangement/position of oil sprayers productivity 500-1000 kg/h on front wall of heating distance of their axes of lateral walls must be not less than 1-1.2 m, but from lower row of sprayers to hearth - not less than 1 m. Furnace depth with the productivity of sprayers 200-250 kg/h must comprise not less than 3 m, but with the productivity 500 kg/h and above - not less than 4 m.

19. For normal operation of oil sprayers is necessary preheating petroleum residue to temperatures, which provide required viscosity/ductility/toughness (see RN 3-02).

For the mechanical burners maximum permissible viscosity/ductility/toughness 6 recommended ~3.5°UV (relative viscosity). For the steam jets the maximum permissible viscosity/ductility/toughness 15, recommended with ~7° UV.

20. During calculation of burner devices quantity of primary air for carbon/coals, schists and milling peat is recommended to select in accordance with data of Table 11, connecting it with results of thermal design of dust-system.

For the petroleum residue and the gas entire organizationally applied into the heating air should be supplied to the root of torch.

C) Heatings for layered combustion.

21. Selection of type of heating for layer combustion in depending on form of fuel/propellant and steaming capacity of boiler aggregate/unit should be produced in accordance with recommendations given in Table 12.

22. In cases of installation of layer heatings under boilers by steaming capacity more than 20 m/h recommendations remain the same as for boilers with D=20 m/h.

23. Height of heating for boilers with steaming capacity 4-10 m/h one should assume/take 2.5-4.0 m, for boilers by productivity 20-35 m/h - not less than 4 m.

24. Active length of grate bar fabric/bed must be: a) with manual fueling - not are more than 2.3 m;

a) with manual loading of fuel/propellant - not more than 2.3 m;

b) with mechanized load to rigid lattice - not are more than 3.5 m;

c) with mechanized load to moving lattice/grid - not are less than 4.5 m.

25. Furnace chambers/cameras of layer mechanical and semimechanical heatings, designed for combusting carbon/coals, anthracites and schists, it should be equipped highly raised with front/leading and low that omitted by rear with arches/summaries, which overlap about half grate bar fabric/bed.

In the upper graphs/counts on each position are shown the recommended types of combustion systems, into the lower ones - those substituting.

Table 9. Minimum speeds of gas-air mixture (on volume of mixture with 0°C and 760 mm Hg) in the neck/throat of the flameless burners for the blast-furnace gas, nm/s.

| (1) Содержание водорода в газе | (2) Диаметр горловины, мм | | | | | |
|---|---|---|---|---|---|---|
| | 200 | 250 | 300 | 350 | 400 | 450 |
| | (3) Минимальная скорость, нм/сек | | | | | |
| (4) Не более 4% . . | 2,0 | 2,2 | 2,4 | 2,6 | 2,8 | 3,0 |
| (5) До 10% . . . . | 3,6 | 4,0 | 4,3 | 4,6 | 4,9 | 5,0 |

Key: (1). Content of hydrogen in the gas. (2). Diameter of neck/throat, mm. (3). Minimum speed, nm/s. (4). Not more. (5). To.

Table 10. Air speeds in mazut and gas burners in the narrowest section of embrasure

| (1) Вид топлива и тип горелки | (2) Скорость, м/сек |
|---|---|
| (3) Мазут (механическое распыливание, вентиляторное дутье) | 20÷35 |
| (4) Мазут (паровое распыливание, без вентиляторного дутья) | 5÷8 |
| (5) Природный газ (газовые и газо-мазутные горелки) . . | 20÷35 |

Key: (1). Form of fuel/propellant and type of burner. (2). Speed, m/s. (3). Petroleum residue (mechanical atomization/pulverization, ventilator blowing). (4). Petroleum residue (steam atomization/pulverization, without ventilator blowing). (5) natural gas (gas and gas-oil burners).

Table 11. Quantity of primary air.

| (1) Топливо | (2) Выход летучих на горючую массу, % | (3) Процент первичного воздуха от количества воздуха, подаваемого в топку | |
|---|---|---|---|
| | | (4) Пылеугольные топки | (5) Шахтно-мельничные топки |
| (6) АШ и полуантрациты | 2÷9 | 20÷25 [1] | — |
| (7) Тощие угли | 10÷17 | 20÷25 | — |
| (8) Каменные угли | 17÷30 | 25÷30 | — |
| (9) То же | 30÷50 | 30÷45 | 30÷45 |
| (10) Бурые угли | >35 | 40÷45 | 40÷50 |
| (11) Сланцы | 80÷90 | 50÷60 | 50÷60 |
| (12) Фрезерный торф | 70 | — | 50÷70 |

Key: (1). Fuel/propellant. (2). Yield of volatile components to combustible mass. (3). Percentage of primary air from quantity of air, supplied for heating. (4). Pulverized-coal combustors. (5). Shaft-mill heatings. (6). ASh and carbonaceous coal. (7). Lean coal. (8). Bituminous coal. (9). Then. (10). Brown coal. (11). Schists. (12). Milling peat.

FOOTNOTE [1]. Recommendations are given for the diagram with the supply of dust by hot air. During the supplying to dust by mill air a quantity of primary air must be reduced to 15-20o/o for ASh and semianthracites.

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Table 12. Recommended types of layer heatings.

| (1) Топливо | (2) Паропроизводительность котлов, т/час | | |
|---|---|---|---|
| | <2 | 4÷10 | 12÷20 |
| (3) Антрацит (АРШ, АСШ, АС, АМ) | (4) Топка с забрасывателем[1] | (6) Топка с цепной решеткой[2] | (5) Топка с цепной решеткой |
| | Топка с ручным (7) забросом | — | — |
| (8) Тощие угли (только из шахт, выдающих слабо спекающиеся угли) | (4) Топка с забрасывателем | | — |
| | Топка с ручным (7) забросом | — | — |
| (9) Каменные угли пламенные неспекающиеся | (10) Топка с забрасывателем Топка с шурующей планкой[3] | | Топка с цепной решеткой и забрасывателем. Топка с цепной решеткой (11) |
| | Топка с ручным (7) забросом | — | — |
| (12) Каменные угли[1] пламенные спекающиеся | (10) Топка с забрасывателем Топка с шурующей планкой[3] | (13) | Топка с цепной решеткой и забрасывателем |
| | Топка с ручным (7) забросом | — | — |
| (14) Бурые угли умеренной влажности ($W^п \leq 6$) | (10) Топка с забрасывателем Топка с шурующей планкой[3] | | Топка с цепной решеткой и забрасывателем. Топка с цепной решеткой (11) |
| | Топка с ручным (7) забросом | Топка с наклонно-переталкивающей решеткой (15) | |
| (16) Бурые угли повышенной влажности ($W^п = 6 \div 15$) | (10) Топка с забрасывателем Топка с шурующей планкой[3] | (13) | Топка с цепной решеткой и забрасывателем |
| | Топка с ручным (7) забросом | Топка с наклонно-переталкивающей решеткой (16) | — |
| (17) Торф кусковой при $W^р = 45 \div 50\%$ и $A^с \leq 11\%$ (17a) | (18) Шахтная топка[4] | (19) | Шахтно-цепная топка[5] |
| | — | — | — |
| (20) Сланцы | Топка с забрасывателем (21) | Топка с наклонно-переталкивающей решеткой (15) | |
| | — | — | — |
| (22) Древесные отходы | (23) Скоростная топка ЦКТИ системы Померанцева | | |
| | (24) Финская топка (с наклонной решеткой) | | |

Key: (1). Fuel/propellant. (2). Boiler steam capacity, m/h. (3).

Anthracite. (4). Heating with spreader [1].

FOOTNOTE [1]. The combustion of fine anthracites under the boilers with D<10 m/h is undesirable because of the small efficiency/cost-effectiveness of mechanized of fuels used. ENDFOOTNOTE.

(5). Heating with chain grate. (6). Heating with chain grate [2].

FOOTNOTE [2]. For the boilers by steam capacity of 10 m/h. ENDFOOTNOTE.

(7). Heating with manual throw/excess/overshoot. (8). Lean coal (only from mines/shafts, salient weakly caking coal). (9). Bituminous coal ardent not caking. (10). Heating with spreader. Heating with the poking lath [3].

FOOTNOTE [3]. For the boilers by steaming capacity to 12 m/h. ENDFOOTNOTE.

(11). Heating with chain grate and ejector. Heating with the chain grate. (12). Bituminous coal ardent sintering. (13). Heating with chain grate and spreader. (14). Brown coal of moderate humidity. (15). Heating with obliquely pushing lattice/grid. (16). Heating with obliquely pushing lattice/grid. (17). Peat of lump with. (17a). and.

(18). Mine/shaft heating [4].

FOOTNOTE [4]. For the boilers by steaming capacity to 6.5 m/h. ENDFOOTNOTE.

(19). Mine-chain/catenary furnace[5].

FOOTNOTE [5]. For the boilers by steaming capacity 10-230 m/h. ENDFOOTNOTE.

(20). Schists. (21). Heating with spreader. (22). Wood withdrawals/departures. (23). High-speed/high-velocity heating of TsKTI system of Pomerartsev. (24). Finnish heating (with inclined lattice/grid).

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In torch- layer heatings and heatings with the manual throw/excess/overshoot of chamber/camera one should perform opened.

26. In the case of supply into layer heatings of secondary air quantity of it must compose 8-15c/c of necessary for combustion. The exit velocity of this air from the nozzles should be assumed/taken 40-60 m/s. For torch- layer heatings a quantity of secondary air can

be increased to 20-25o/c.

E. Heating surfaces.

q) General consideraticns.

27. Temperature of stack gases boiler unit should be selected from consideraticns abcut sufficiently effective use cf heat cf fuel/propellant with relatively lcw experditure cf metal for construction of tailed heating surfaces. This temperature for the powerful/thick boilers is located on the lower level than for the low-power reactors.

For the boilers with productivity D>12 m/h at the assigned values of the temperatures cf feed water and air at the entrance intc the air heater the temperature of stack gases should be determined, assuming/taking thermal heads at the cold end cf the economizer about 40-50°C and at the hct end cf the cold step/stage of air heater (cr entire air heater with its single-stage laycut) about 30-40°C.

Temperature of air at the inlet intc the air heater for the purpose of averting chcking by the ashes of the heating surface must be selected to the apprcximately equal temperature cf the condensation of water vapors, which corresponds to their partial

pressure in the gases.

For the solid fuels to this condition correspond the temperature of airs at the inlet into the air heater, shown in Table 13. For these temperatures and two assumed values of the temperature of feed water are calculated at recommended values indicated above of thermal heads of the temperature of stack gases, also given in Table 13.

For the sulfurous fuels/propellants the dewpoint of flue gases considerably exceeds the temperature of the condensation of pure/clean water vapors, determined on their partial pressure in the gases, since in this case on the cold surfaces is condensed the solution of sulfuric acid. With the given content of sulfur in fuel $S^{\cdot}$ 0.25 - 2o/o/thous. kcal/kg, temperature of the dew point composes 120-150°C.

Under these conditions the protection of air heaters from the gas corrosion by an increase in the temperature of the wall higher than the dew point would lead to the inadmissibly high temperature of outgoing gases. Therefore feast the combustion of sulfurous fuels/propellants of the temperature of air at inlet into the air heater and stack gases is recommended to select without taking into account an increase in the dewpoint. Consequently, Table 13 must be used also for the sulfurous fuels/propellants.

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THERMAL DESIGN OF BOILER UNIT (STANDARD METHOD).(U)
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For warning/preventing of gas corrosion or weakening of its harmful consequences in this case should be taken the special measures: the guarantee of light replacement of the corroded sections, the use/application of the corrosion resistant materials and coatings, the use/application of special schematics of layout, which prevent most the corrosively dangerous temperatures of wall, close ones to the dewpoint, and using a range of temperatures of wall with the relatively low speed of corrosion at lower temperatures, use/application of special constructions/designs of the series-connected air heaters, etc.

For the low-power reactors ($D \leq 12$ m/h), which have the tailed heating surfaces, the temperature of stack gases must start by higher than the values, indicated in Table 14.

28. Preheating air, supplied to heating during chamber combustion, is recommended in limits, indicated in Table 15.

For the layer heatings of boilers by steaming capacity less than 12 m/h preheating air is not required, with exception of the cases when work on cold air does not ensure stability and effectiveness of the burning process (see BN 5-03).

Table 13. Temperatures cf stack gases and air at the entrance into the air heater for the tcilers with D>12 m/h/

| (1) Топливо | (2) Температура воздуха на входе в воздухоподогреватель, °C | (3) Температура уходящих газов, °C | |
|---|---|---|---|
| | | (4) Высокое давление ($t_{п.в}$ =215° C) | (5) Среднее давление ($t_{п.в}$ =150° C) |
| (6) Сухое, $W^п$ = 2 . . . . . | 30 | 120÷130 | 110÷120 |
| (7) Влажное, $W^п$=5÷20 . . | 45÷55 | 140÷150 | 120÷130 |
| (8) Сильно влажное, $W^п$>25 | 60÷65 | 160÷170 | 130÷140 |

Key: (1). Fuel/propellant. (2). Temperature cf air at the inlet into air heater, °C. (3). Temperature cf stack gases, °C. (4). High pressure. (5). Mean pressure. (6). Dry. (7). Mcist. (8). Strcngly moist.

Table 14. Temperature cf stack gases for the tcilers with D<12 m/h.

| (1) Топливо | (2) Температура уходящих газов, °C |
|---|---|
| (3) Угли с $W^п \leq 6$ . . . . . | 160÷180 |
| (3) Угли с $W^п$=6÷16 . . . | 180÷200 |
| (4) Мазут и природный газ . | 160÷180 |
| (5) Торф . . . . . . . . . | 190÷210 |

Note. The upper limits relate to the tcilers of smaller steaming capacity and the higher temperatures of feed water.

Key: (1). Fuel. (2). Temperature of outgcing gases. (3). Carbcn/coals with (4). Petroleum residue and natural gas. (5). Peat.

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29. When during chamber combustion of fuels/propellants with given humidity >6-8 and schists according to drying conditions of fuel/propellant is not required high preheating of air (for example, in individual extended diagram of pulverized coal preparation), it is expedient to limit its 250-270°C, which will make it possible to use single-stage layout of tailed heating surfaces.

30. Gas velocities according to conditions of averting drift of heating surfaces start with nominal load not below 6 m/s for transversely washed beams and not below 8 m/s for tubular air heaters.

The upper velocity limit of gases is determined by conditions of ash wear. The maximum permissible gas velocities [1] at the entrance into the first on the motion of gases packet of convective mine/shaft (temperature of gases of ~600-700°C) with the nominal load start in accordance with Table 16.

FOOTNOTE 1. The speed of gases, achieved by wear conditions, in the case when the diagonal section for the passage of gases is smaller than transverse (in contrast to computed speed during calculation of heat emission, is determined by the diagonal section. ENDFOOTNOTE.

For the coal-dust slag-tap boilers, and also for the boilers with the layer heatings, the maximum permissible gas velocity until further refinement of the data about the fractional composition and the coefficient of the abrasiveness of ashes is determined approximately by the method of the conversion of the value of speed for the boilers with the dry slag disposal inversely proportional to

root cubic from the relation of the values cf the extension cf ashes from the heating.

The values of the maximum permissible speeds fcr the boiler beams of the multidrum boilers cr cld ccrstructions/designs with the pulverized-coal combustcrs should be determined according to application/appendix tc the circular technical instruction MES No T13 "About warning/preventicr cf emergencies with the boilers because cf damage of the heating surface as a result of cinder erosion", but in this case they must not exceed values indicated in Table 16.

Table 15. Temperature cf preheating air.

| (1) Характеристика топки | (2) Сорт сжигаемого топлива | (3) Рекомендуемая температура горячего воздуха, °C |
|---|---|---|
| (4) Топки с сухим шлакоудалением при замкнутой схеме сушки топлива | (5) Каменные угли, сланцы северо-западных месторождений и другие топлива с приведенной влажностью до 8% | 250÷300 |
| (6) То же | (7) Волжские сланцы | 320÷350 |
| (6) То же | (8) Антрацитовый штыб и тощие угли | 380÷420 |
| (9) То же, включая пневматические топки ЦКТИ | (10) Бурые угли, фрезерный торф и другие топлива с приведенной влажностью больше 8% | 380÷420 |
| (11) Топки с жидким шлакоудалением, в том числе циклонные | (12) Независимо от вида сжигаемого топлива | 380÷420 |
| (13) Камерные топки | (14) Мазут и природный газ | 200÷300 |
| (6) То же | (15) Доменный газ | 250÷350 |

Note. The recommended values cf the temperatures of preheating air, supplied to the layer heatings, are shown in RN 5-03.

Key: (1). Characteristic of heating. (2). Type cf burned fuel/propellant. (3). Recommended temperature cf hot air, °C. (4). Heatings with dry slag disposal in locked diagram of drying cf fuel/propellant. (5). Bituminous coal, schists cf northwestern layers and other fuels/propellants with given humidity to 8o/o. (6). Then. (7). Volga schists. (8). Anthracite fines and lean coal. (9). Then, including pneumatic heatings cf TsKTI. (10). Brown coal, milling peat and other fuels/propellants with given humidity are more than 8o/o. (11). Liquid-bath furnaces, including cyclonic. (12). Independent of form of burned fuel/propellant. (13). Chamber furnaces. (14). Petroleum residue and natural gas. (15). Blast-furnace gas.

Table 16. Maximum permissible gas velocities according to the conditions for cinder erosion.

| (1) Сорт топлива | (2) Способ сжигания | Предельно допустимая скорость, (3) м/сек |
|---|---|---|
| (4) Подмосковный уголь | (5) Пылевидный, шаровые барабанные мельницы | 10,0 |
| (6) То же | (7) Шахтно-мельничная топка | 9,0 |
| (8) Антрацитовый штыб | (9) Пылевидный, шаровые барабанные мельницы | 10,5 |
| (10) Донецкий тощий | (6) То же | 14,0 |
| (11) Челябинский уголь | » » | 10,0 |
| (12) Кизеловский уголь | » » | 9,5 |

Key: (1). Type of fuel/propellant. (2). Ignition method. (3). Maximum permissible speed, m/s. (4). Mcsccw carbcn/ccal. (5). Pcwdered, ball rattlers. (6). Then. (7). shaft- mill heating. (8). Anthracite fines. (9). Powdered, ball rattlers. (10). Donets emaciated. (11). Chelyabinsk carbon/coal. (12). Kizelcvskiy carbcn/ccal.

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31. Spacings between tubes in convective surfaces of heating should be assumed/taker in accordance with limits, indicated in Table 17.

Recommendations by choice cf steps/pitches for the air heaters are given in the appropriate division.

32. To tailed surface of heating low-pressure bcilers by

steaming capacity less than 12 m/h it should be made by that consisting of elements of feed-water economizer, and of separate cases of elements of air heater.

With the boiler steam capacity D$\geqslant$12 m/h it is usually expedient to perform "tail" by that consisting of the feed-water economizer and the air heater.

With the nondeaerated feed water for the boilers with the pressure of steam to 22 Am(gage) inclusively is recommended the using of cast iron ribbed economizers. The start of boiling of water in the cast iron feed-water economizers is inadmissible. The maximum temperature of the heated in them water must be, in accordance with boiler code, at least on 40°C below boiling point.

In the boiler installations of small power, which work with the frequent stoppages and changes of the loads over wide limits, is usually expedient installation of cast iron air heaters.

b) Water shields and boiler heating surfaces.

33. Spacings between tubes for screens should be selected according to data of Table 18.

34. Screens of unilccular liquid-bath furnaces in part, which adjoins hearth of first chamber/camera of dual chamber heatings, and also precombustion chambers of cyclonic heatings should be studded with coating with their fireproof mass.

35. For guaranteeing steady propellant ignition with small /yield of volatile components (anthracites, carbonaceous coal, and in completely slag screened fireboxes of boilers with D<75 m/h and sometimes larger productivity - lean coal) in chamber furnaces must be established/installed igniting belts/zones.

36. Warmed pipes of screens and convective evaporative surfaces of heating boilers it is expedient to make with inside diameter not more than 50 mm.

c) Superheaters.

37. Diameter of pipes of superheaters can been selected over wide limits; it should be by 28-42 mm.

Table 17. Spacings between tubes.

| (1) Наименование поверхности | (2) Расположение труб | (3) Поперечный относительный шаг $s_1/d$ | (5) Продольный относительный шаг $s_2/d$ |
|---|---|---|---|
| (4) Фестон и фестонированные части котельных пучков[1] и перегревателей | (5) Шахматное | ≥4,5 | ≥3,5 |
| (6) Котельные пучки и экономайзеры | » | 2,0÷3,0 | 1,0÷1,5[2] |

Key: (1). Designation cf surface. (2). Run cf pipes. (3). Transverse relative step/pitch $s_1/d$. (4). Festoon and festconed part cf tciler teams[1] and heaters.

FOOTNOTE [1]. In toilers by steaming capacity 5C m/h it is above for the part of the lateral screens, tc the adjacent the rear wall yes length of 1.0-1.5 m, one should assume/take relative spacing tetween tubes s/d<1.3. ENDFOOTNCTE.

(5). Chess. (6). Boiler teams and economizers.

FOOTNOTE [2]. Preference should te returned equipass teams with $(s_1-d)-2$ $(s'_2-d)$, where $s'_2$ - diagcnal spacer. ENDFCOTNOTE.

Table 18. Spacings between tubes of screens.

| (1) Паропроизводительность котла | (2) Наименование экранов | (3) Относительный шаг труб s/d |
|---|---|---|
| | (5) 1. Котлы с камерными топками | |
| (4) 12÷110 т/час | (6) Задний экран | ≤1,3 |
| | (7) Экран свода, боковые[1] и фронтовой экраны[2] | ≤1,8÷2,0 |
| (8) 110 т/час и выше | (9) Все гладкотрубные настенные экраны[3] | ≤1,25 |
| | (10) Двухсветные и ширмовые экраны | ≤1,2 |
| | (11) Ошипованные экраны | ≤1,25 |
| | (12) 2. Котлы со слоевыми топками | |
| (4) До 10 т/час | Все экраны топки | ≤2,5 |
| 12 т/час и выше (8) | То же | ≤2,0 |

Key: (1). Boiler steam capacity. (2). Designaticn of screens. (3). Relative spacing between tubes. (4). m/h. (5). Boilers with chamber furnaces. (6). Rear screen. (7). Screen cf arch/summary, lateral [1] and front screens [2].

FOCTNOTE [1]. In boilers by steaming capacity 50 m/h it is above for the part of the lateral screens of that adjcining the rear wall at the length of 1.0-1.5 m, is reccmmended to assume/take relative spacing between tubes $s/d \leqslant 1.3$.

[2]. For strongly slagging fuels/propellants spacing between tubes of screens of arch/summary, frcrt and lateral shculd be decreased to $s/d \leqslant 1.3$-$1.4$. ENDFOOTNOTE.

(8). m/h it is above. (9). All plain-tube wall cf shield [3].

FOCTNOTE [3]. For few slagging fuels/propellants spacing between tubes

of screens can be allowed tc s/d≤2. ENDFCOTNCTE.

(10). two-light and screen screens. (11). studded screens. (12). Boilers with layer heatings.

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When selecting of diameter and number of pipes cf superheaters it is necessary to ensure maximally possible speeds pair in those sections of the superheater, where the safety factors are minimum, i.e., where the temperatures of the wall of pipes, checked using the indications cf Appendix IV, it is most close tc the maximum permissible temperatures for this metal. In this case the hydraulic resistance cf superheater (from the cutput/yield pair from the boiler barrel to the main steam cutoff device/equipment inclusively) must not exceed 10o/o cf operating pressure pair.

38. For guaranteeing reliable work cf superheaters with temperature of superheated steam of 500°C or above is compulsory division of superheater intc series-connected (cn pair) parts with not less than by two-fold mixing pair in gaps/intervals between them. For overcoming of the aftereffects of gas misalignment should be alsc produced the transfer pair of one part of the flue to another. Mixing pair can be produced with the aid of the mixing

collectors/receptacles with the end hearth cr by outlet, in spray-type attemperator, etc. At temperature cf overheating/superheatirg 450-500°C is also desirable the mixing pair.

39. At average/mean and lcw pressures, ard also usually in radiation high-pressure superheaters to avoid ncnunifcrm distributicn pair according to in parallel included coils is reccmmended the making of supply pair by run of pipes of small diameter all cver length of giving out cellector/receptacle. The use/applicaticn of a diagram P is not recommended, and diagrams Z is not allowed/assumed.

40. Boilers, which have regulation cf cverheating/superheating, must ensure nominal temperature cf superheated steam with steaming capacities 75-100c/o cf nominal.

41. For guaranteeing of reliability and improvement in self-regulaticn of heater it is expedient at temperature of superheated steam of 500°C cr tc above use twc-step regulaticn of overheating/superheating. As the second step/stage shculd be used spray-types attemperatcr.

42. For regulating cverheating/superheating in bcilers cf mean pressure it is pcssible tc use surface/skin steam ccclers, placed in collectors/receptacles cf saturated steam or intermediate. Hcwever,

in this case the use/application of spray-types attemperator has advantages, since it improves the condition for automatic regulation.

During the setting up of surface/skin steam coolers the feed water, which goes through the steam cooler, should be returned to the feeder line to the economizer.

43. Surface of heating superheater during calculation of boiler aggregate/unit without rotary burners for nominal load is determined taking into account heat absorption in steam cooler, equal to 10-20 kcal/kg pair. Lower limit is shown for the superheaters the part of surface of which is placed in the heating, or, for the case of positioning/arranging the entire surface after the festoon, the working at temperature gases at the entrance it is higher 1000°C. The upper limit is shown for the purely convective superheaters, which work at temperature of gases at the entrance of lower than 900°C.

Steam cooler relies on heat abstraction of approximately 25-30 kcal/kg pair under standard conditions. Circuit diagram and construction/design of steam cooler must provide the possibility of a peak increase in the heat removal to 50-60 kcal/kg pair.

d) Economizers.

44. Outside diameter of pipes of steel economizer is reccmmended in limits of 28-38 mm. The use/application cf pipes of smaller diameter is mcre expedient.

45. With U-shaped layout ccils of econcmizer should be arranged/located in parallel back wall of bciler. In this case the intensive wear, caused by an increase in ashes ccncentration on external generatrix cf rctaticn, undergo not all coils, but cnly adjacent to the external wall mines/shafts.

The transverse locaticn cf ccils is allcwed/assumed during the combustion of liquid and gaseous fuels, and alsc during the use/application of heatings with the high ccefficient of slag skimming.

46. Distance between adjacent steps/stages of economizer and air heater should be not less than 800 mm for guaranteeing possibility of inspection and surface cleaning of heating.

Between the separate packets of the coils of the econcmizers cf the boilers of average/mean and large power must be provided for the breaks/ruptures in height nct less than 550-600 mm. The height of packet must be nct mcre than 1 m with clcse run of pipes ($s_2/d \leqslant 1.5$) and nct more than 1.5 m during the rare location.

Breaks/ruptures in height not less than 550-600 mm must be provided for also between groups of the cast-iron pipes of economizer. In each group is desirable to have not more than eight - ten rows on the height.

47. With layout of economizer "into splitting" from air heater for guarantee is possible smaller exapnsion of temperatures of water on separate coils is recommended the achieving of its full/total/complete mixing with transfer from first stage of economizer to upper.

48. Speed of water in steel "nonboiling" economizers or "nonboiling" part of "boiling" economizers must not be less than 0.3 m/s with nominal load of boiler. In the "boiling" part of the "boiling" economizers to avoid overheating/superheating pipes with the stratification of steam-water mixture the speed of water must not be less than 1.0 m/s. In this case the isolation/liberation of part from the increased by speed water is produced so that the underheating up to the boiling in the beginning of it would be not less than 40°C.

For maintaining sufficient speeds of water it is possible to use

serpentine steel economizers with the bends in several planes instead of the usual simple coils with the bends in one (vertical) plane.

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49. When selecting of diameter and number of pipes of economizer it is necessary to ensure value of hydraulic resistance of economizer for boilers high(ly)-that of pressure not more than 5o/o and for boilers of mean pressure not more than 8o/o pressure in boiler barrel.

e) Air heaters.

50. Tubular air heaters should be made from pipes with a outside diameter of 40-51 mm in thickness of wall 1.5 mm. The use/application of pipes in outside diameter less than 40 mm is heat-technically expedient, but yet was not obtained sufficiently wide operational checking. Is recommended chess run of pipes.

For decreasing the overall sizes it is expedient clearances between the pipes of air heater in the diagonal direction to make with minimum ones. According to the conditions of technology minimally permissible gap length is approximately/exemplarily 10 mm. The transverse pitch of pipes is selected from the conditions of

cross-section equality fcr the passage of air in the transverse and diagonal directions.

51. Are recommended following exemplary/approximate relationships/ratios of air speeds and gases:

for tubular air heaters ... $w_в/w_г = 0,5;$

for ribbed- toothed of air heaters ... $w_в/w_г = 0,7;$

for lamellar and ribbed air heaters ... $w_в/w_г = 1,0.$

EXEMPLARY/APPROXIMATE THERMAL DESIGN OF BOILER AGGREGATE/UNIT.

Exemplary/approximate thermal design is given for the purpose of showing, as should be used the materials of standards, and tc illustrate the order of performance of calculation. For this is selected check calculation as is mcre complicated.

For fulfilling the calculation is accepted a contemporary Soviet boiler aggregate/unit cf the type BK-10, they are represented in Fig. 14.

Task.

Boiler steam capacity (Nominal) ... D=230 m/h.

Pressure of steam at the output from the superheater (after steam turbine throttle) ... $p_{nn} = 101$ atm (abs.).

Pressure in the boiler barrel $p_{\kappa} = 110$ atm (abs.).

Temperature of superheated steam $t_{nn} = 510°$ C.

Temperature of feed water $t_{n.в} = 215°$ C.

Percentage of scavenging ... $g_{np} = 1.5\%$.

Fuel/propellant - withdrawals/departures of the enrichment of carbon/coals of the donets pond of brand PPM.

System is dust-prepared - ShEM, locked diagram of drying.

STRUCTURAL/DESIGN CHARACTERISTICS OF AGGREGATE/UNIT.

a) Furnace chamber/camera (Fig. 15a).

Surface of the walls of the furnace chamber/camera:

Side wall

$$F_1 = \frac{4,500 + 7,600}{2} 2,215 = 13,4 \ м^2;$$
$$F_2 = 7,600 \cdot 11,235 = 85,5 \ м^2;$$
$$F_3 = \frac{7,600 + 7,20}{2} 0,94 = 6,95 \ м^2;$$
$$F_4 = \frac{7,20 + 0,8}{2} 4,40 = 17,6 \ м^2;$$
$$F_5 = \frac{0,8 + 0,5}{2} 0,40 = 0,26 \ м^2.$$
$$F_{ст.б} = 123,7 \ м^2.$$

Front wall (with the ceiling and the adjacent part of the cold funnel)

$$F_{ст.ф} = 9,785 (2,250 + 2,705 + 12,175 + 7,20) = 238 \ м^2.$$

Rear wall (with the adjacent part of the cold funnel)

$$F_{ст.з} = 9,785 (2,250 + 2,705 + 11,235) = 158 \ м^2.$$

Note. Linear dimensions start with an accuracy to 1 mm, if they are shown on the drawing. The sizes/dimensions, not indicated on the drawing, but determined on the scale or the calculations, start with an accuracy to within two-one signs after comma.

Festoon

$$F_ф = 9,785 \cdot 5,84 = 57,1 \ м^2.$$

Summary surface of the walls of the furnace chamber/camera

$$F_{ст} = 2F_{ст.б} + F_{ст.ф} + F_{ст.з} + F_ф = 2 \cdot 123,7 + 238 + 158 + 57,1 = 700 \ м^2.$$

Not shielded of surface it is net, occupied with burners,

$$F_{гор} = 9 \ м^2.$$

Surface of walls of heating, closed with screens,

$$F_{ст.э} = F_{ст} - F_ф - F_{гор} = 700 - 57,1 - 9 = 634 \ м^2.$$

Diameter and spacing between tubes of all screens are identical. Therefore the beam-receiving surface of screens is calculated together from one value of angular coefficient.

Diameter of screen pipes d=76 mm.

Spacing between tubes s=95 mm.

$$\frac{s}{d}=\frac{95}{76}=1,25.$$

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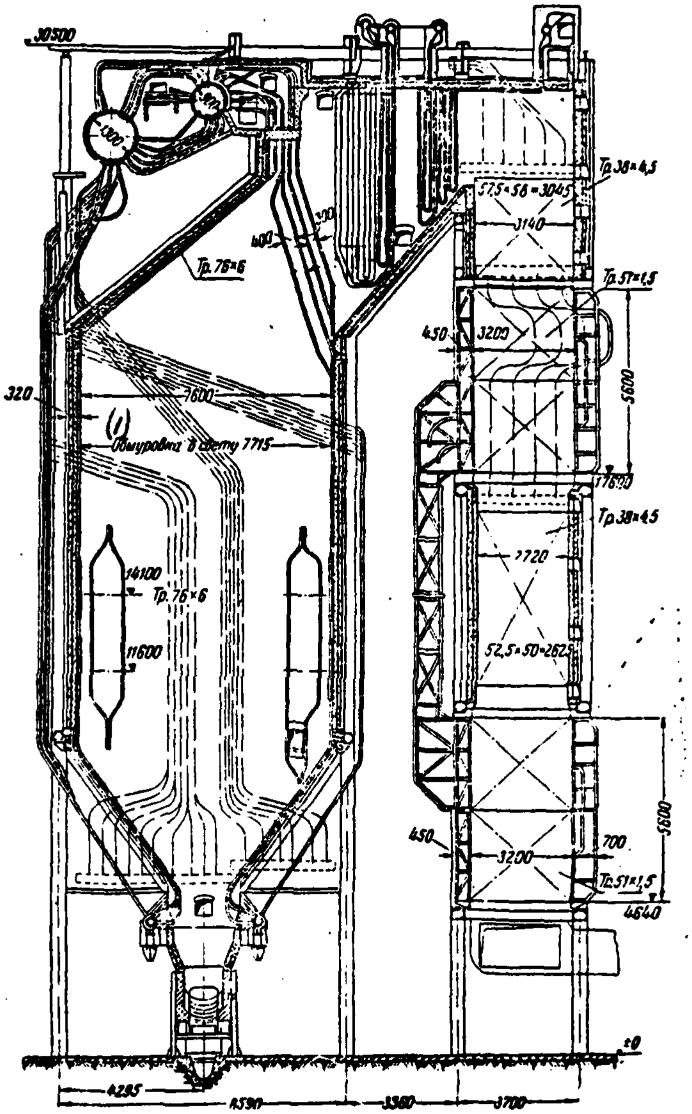


Fig. 14. Longitudinal section of boiler EK-10 (to exemplary/approximate thermal design).
Key: (1) Brickwork clearance.

Page 126. Relative distance of pipes from the wall

$$\frac{e}{d}=\frac{57,5}{76}=0,76\approx 0,8.$$

Angular coefficient $x$=0.98 (on RN 6-02).

Beam-receiving surface of the screens

$$H_{л.э}=xF_{ст.э}=0,98\cdot 634=620\ м^2.$$

Beam-receiving surface of the festoon

$$H_{л.ф}=xF_{ф}=1,0\cdot 57,1=57,1\ м^2.$$

Summary beam-receiving surface of the heating

$$H_{л}=620+57,1=677\ м^2.$$

Degree of the screening of the heating

$$\psi=\frac{H_{л}}{F_{ст}}=\frac{677}{700}=0,969.$$

Volume of furnace chamber/camera (work of the area of lateral wall to the width of heating)

$$V_{т}=123,7\cdot 9,785=1\,210\ м^3.$$

b) Festoon (Fig. 15b).

Diameter of pipes 76x6 mm. Run of pipes - chess.

Spacings between tubes $s_1$=380 mm; $s_2$=300 mm.

Number of rows on the action of gases $z_2$=4.

Number of pipes in the first and third rows - on 26, the secondly and the fourth on 25. length of pipes: first row 6.9, the second - 5.7, the third - 6.0 m, the fourth - 6.1 m.

Surface of heating the festoon

$$H_{\phi} = (26 \cdot 6{,}9 + 25 \cdot 5{,}7 + 26 \cdot 6{,}0 + 25 \cdot 6{,}1)\, 3{,}14 \times \times 0{,}076 = 150\ м^2.$$

Sections for the passage of the gases:

$$F' = 6{,}0 \cdot 9{,}900 - 26 \cdot 5{,}6 \cdot 0{,}076 = 48{,}3\ м^2;$$
$$F'' = 5{,}6 \cdot 9{,}900 - 25 \cdot 4{,}9 \cdot 0{,}076 = 46{,}2\ м^2.$$

In view of the insignificant difference between F' and F'' calculated clear opening is defined as mean arithmetic

$$F = \frac{48{,}3 + 46{,}2}{2} = 47{,}2\ м^2.$$

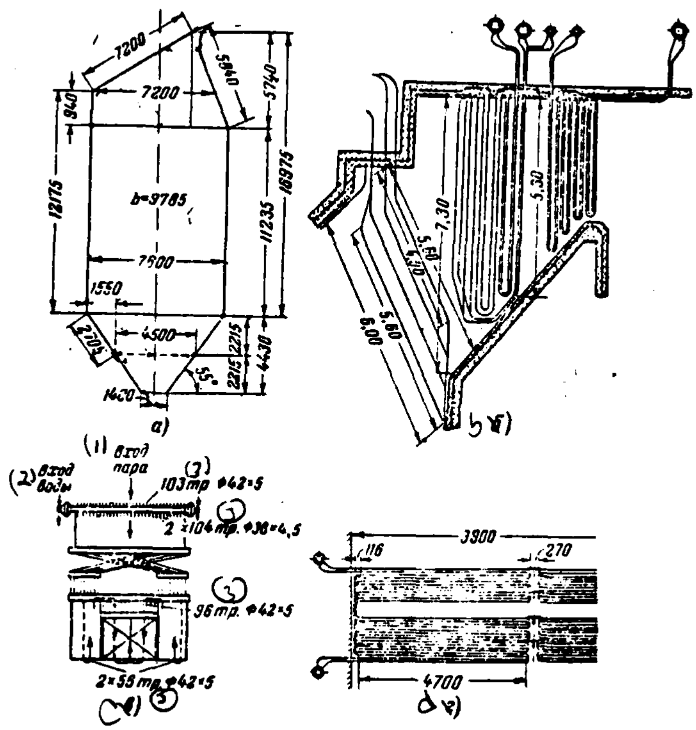


Fig. 15. Diagram of gas conduits of boiler EK-10 a) the furnace chamber/camera; b) festccn and superheater; c) the diagram of the superheater; d) econcmizer (seccnd step/stage).

Key: (1). entrance of steam . (2). entrarce cf water. (3). tr.

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Relative spacings between tubes:

transverse $\frac{s_1}{d} = \frac{380}{76} = 5{,}00;$

longitudinal $\frac{s_2}{d}=\frac{300}{76}=3{,}95.$

Average/mean effective thickness of radiaticn layer

$$s=\left(2{,}82\frac{s_1+s_2}{d}-10{,}6\right)\cdot d=$$
$$=[2{,}82\,(5{,}00+3{,}95)-10{,}6]\,0{,}076=1{,}11\ м.$$

Angular coefficient of the row of festocn without taking into account the radiation/emissicn cf brickwcrk $x_{pяда}=0{,}29.$

Angular coefficient of the festccn

$$x_{\phi}=1-(1-x_{pяда})^4=0{,}746.$$

Beam-receiving surface cf the beam of the festccn

$$H_{л.ф}=0{,}746\cdot 57{,}1=42{,}6\ м^2.$$

c) Superheater (Fig. 15b and c).

Superheater consists cf twc consecutively/serially (on the gases) arranged/located parts and has the ccmpound circuit of steam flow.

The saturated steam frcm the drum is sent for the steam cooler along 103 ceiling warmed pipes $\varnothing$ 42×5 мм. which close ceiling all over length of superheater in the gaps/intervals between the coils. Frcm steam cooler the vapor is abstracted/remcved by twc runs of

pipes ⌀ 38 × 4.5 mm along 104 pipes in the row; these pipes partially overlap the ceiling of rotary chamber/camera and then they directly pass into the coils firstly on the motion of steam on the part of the superheater. Steam in this part moves always countercurrent with respect to the gases.

The coils of first steam stage of superheater are introduced into the intermediate collector/receptacle. From this collector/receptacle of steam with ten times overflow pipes is supplied into the inlet effusor of second steam stage. For more uniform distribution of temperatures of steam on the coils it with the bypass is redistributed along the sides and in the width of the flue: steam from the middle part of the left half flue it is supplied into the extreme part of the right half, and vice versa.

The first on the motion of gases part of the superheater consists of two consecutively/serially (on steam) included parts: first, that consists of two extreme sections on 28 dual coils of each, and the secondly, average, section of 48 dual coils. Circuit diagram with respect to the gas flow for all three sections is identical: steam enters the latter on the motion it is single dual run of pipes, are sunk downward and it passes into the first on the motion of gases four runs of pipes. Further steam moves with unidirectional flow with respect to the gases.

The diagram of mutual flow direction of steam also of gases both parts of the superheater does not make it possible to calculate thermal head for entire superheater as a whole, if it fails condition (7-68) about the relationship/ratio of the values of thermal head, calculated for pure/clean anti- and unidirectional flow.

In the case of separate calculation the first according to the motion of gases part is calculated as heat exchanger with an in parallel-mixed current with two motions of multipass medium, moreover both motions with the unidirectional flow with respect to the single-pass medium (see curve 1 of nomogram XIV). The adoption of this diagram is admissible because ratio between areas of top and bottom wings of both motions on steam (both extreme sections should be considered as one motion with respect to steam) (2•28/48)=1.17<1.5 (see Section 7-63); the fraction/portion of heat absorption, which falls to last on the motion of gases dual run of pipes (which on the location does not correspond to the diagram of unidirectional flow), it is small, and this deviation from the diagram accepted is not considered.

The second on the motion of gases part of the superheater is countercurrent. In view of the fact that the heat absorption of steam

cooler is great in relation to the heat absorption of this part of the superheater, should be expected the nonfulfillment of condition (7-82), in this case it is necessary to separately determine thermal heads of the sections of evaporation and overheating/superheating.

Without depending on that now is determined thermal head (for entire superheater as a whole or for each part separately), the coefficient of heat transfer one should calculate for entire superheater as a whole. Therefore, besides the structural/design characteristics of each part, are calculated the summary and averaged characteristics for entire superheater.

Second (course of steam) step/stage of superheater.

Diameter of pipes 42X 5 mm. Run of pipes corridor, with exception of those chess arranged/located rarefied of the second - the fourth of the rows (first row with the steep pitch works equally with the corridor and staggered arrangements). Since the share of the surface of heating these rows in the total surface of heating entire superheater (second on the motion of gases part also with in-line position of pipes) is insignificant (10o/o), for the calculation it starts that all pipes are arranged/located corridor.

The surface of heating first four rarefied runs of pipes (length

of each of first two rows 6.3, each of second two 6.1 m; since coils partially they go in the overlap of ceiling, their length it is measured to the axis of ceiling pipes)

$$H_1 = 104\,(6{,}3 + 6{,}1)\,3{,}14 \cdot 0{,}042 = 170\ m^2.$$

Surface of heating the following four rows with the increased steps/pitches only along the flow of gases (summary length of first and fourth rows $l_{I,\,IV} = 2 \cdot 5{,}6 + 3{,}14 \cdot 0{,}150 + 0{,}210 = 11{,}9\ m$; the same of second and third rows $l_{II,\,III} = 2 \cdot 5{,}6 + 3{,}14 \cdot 0{,}085 = 11{,}5\ m$)

$$H_2 = 104\,(11{,}9 + 11{,}5)\,3{,}14 \cdot 0{,}042 = 321\ m^2.$$

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Surface of heating remaining nonrarefied runs of pipes of the first on the course of gases part [total length $l=4 \cdot 5.1+2 \cdot 6.5+3.14(0.075+0.130)=34.0$ m]

$$H_3 = 104 \cdot 34{,}0 \cdot 3{,}14 \cdot 0{,}042 = 466 \text{ м}^2.$$

Full/total/complete surface of heating the coils of the second on the course of steam of the part

$$H_{II} = H_1 + H_2 + H_3 = 170 + 321 + 466 = 957 \text{ м}^2.$$

The surface of heating the ceiling ducts, which pass in the limits of this part (length of ducts is determined from the beginning of the warmed part to the middle of the gap/interval between both parts of the superheater; the heating surface is designed from the semicircumference of ducts),

$$H_{\text{пот}_{II}} = 103 \frac{3{,}14 \cdot 0{,}042}{2} 3{,}3 = 22 \text{ м}^2.$$

Since the surface of heating these ducts is less than 4o/o basic heating surface, it is included in the surface consecutively/serially on of vapor of connected with these ducts (by the first on the course of vapor) part of the superheater.

Section/cut for the pass of gases in the rarefied in the width part (in view of the insignificant difference in the heights of section/cut at the entrance into the rarefied part and the output/yield from it calculation it is carried out through medium altitude)

$$F_1=\frac{7,3+6,7}{2}9,900-52\cdot 0,042\cdot 5,4=57,5\ м^2.$$

Section/cut for the pass of gases in the remaining part

$$F_2=\frac{6,5+5,3}{2}9,900-104\cdot 0,042\cdot 5,5=34,4\ м^2.$$

Spacing between tubes in the width of the boiler:

rarefied in the width part $s_{1р}=190\ мм;$

of basic part $s_{1о}=95\ мм.$

The longitudinal pitch of the ducts:

rarefied part $s_{2р}=170\ мм;$

of nonrarefied part $s_{2н}=\frac{375}{5}=75\ мм.$

First (on the course of vapor) stage of superheater.

Surface of heating step/stage (total length of coils)

$$l_1 = 4\cdot 4{,}0 + 4\cdot 3{,}65 + 2\cdot 3{,}20 + 2\cdot 3{,}15 + 4\cdot 2{,}95 + \frac{10 + 2\cdot 0{,}5}{2}(0{,}075 + 0{,}130)\,3{,}14 = 58{,}6\ м;$$

$$H_1 = 104\cdot 58{,}6\cdot 3{,}14\cdot 0{,}038 = 729\ м^2.$$

Surface of heating the ceiling ducts, which pass in the limits of this part before and after steam cooler, switching on the ducts, which close the ceiling of rotary chamber/camera,

$$H_{пот_1} = 104\,\frac{3{,}14\cdot 0{,}042\cdot 4{,}6}{2} + 104\,\frac{3{,}14\cdot 0{,}038\cdot 2{,}4}{2} = 46\ м^2$$

Since ducts are connected both on the vapor and on the gases consecutively/serially of first stage of superheater and the surface of their heating is less than 10o/o $H_1$, they directly are switched on in the surface of heating this step/stage.

Section/cut for the pass of gases (also it is designed according to the average data)

$$F_1 = \frac{4{,}34 + 3{,}25}{2}\,9{,}900 - 104\cdot 0{,}038\cdot 3{,}5 = 24{,}6\ м^2.$$

Spacing between tubes in the width of boiler $s_1$=95 mm;

spacing between tubes in the depth of step/stage $s_2$=1250/15=83 mm.

Structural/design characteristics of superheater as a whole.

Calculated surface of heating second on steam step/stage $H_{II}$ =957 m².

Then of first on steam stage

$$H_1 = 729 + 46 + 22 = 797\ м^2.$$

Then of entire superheater

$$H = 957 + 797 = 1\,754\ м^2.$$

Calculated cross-section for the pass of gases [see formula (7-22)]

$$F_{cp} = \frac{957 + 729}{\frac{170}{57,5} + \frac{321 + 466}{34,4} + \frac{729}{24,6}} = 30,4\ м^2.$$

The calculated diameter of ducts in view of its small difference for both steps/stages is received as the average: d=40 mm.

Run of pipes - corridor, number of runs of pipes - 26.

Calculated spacings between tubes [see formula (7-30)]

$$s_{1cp} = \frac{190 \cdot 170 + 95\,(321 + 466 + 729)}{957 + 729} = 105\ мм;$$

$$s_{2cp} = \frac{170\,(170 + 321) + 75 \cdot 466 + 83 \cdot 729}{957 + 729} = 106\ мм.$$

Efficient thickness of radiation layer within the limits of the tube banks

$$s = \left(1,87\,\frac{105 + 106}{40} - 4,1\right)0,040 = 0,231\ м.$$

Computed value of efficient thickness of radiating layer is determined with the radiation correction of the gas volumes [see formula (7-51)].

Is considered the radiation/emission of two volumes: before the superheater with a depth of $l_{об1} = 1.0$ м (average on the height of coil size), also, between both steps/stages $l_{об2} = 0.8$ м. General/common/total depth of tube banks of both steps/stages of the superheater

$$l_{п} = 1{,}73 + 1{,}25 = 2{,}98 \text{ м};$$
$$s' = 0{,}231 \frac{2{,}98 + 0{,}5(1{,}0 + 0{,}8)}{2{,}98} = 0{,}301 \text{ м}.$$

Sections/cuts for the pass of vapor:

first on the vapor stage

$$f_1 = 208 \cdot 0{,}029^2 \cdot 0{,}785 = 0{,}137 \text{ м}^2;$$

the extreme bundles of the second on the vapor step/stage

$$f_{2к} = 112 \cdot 0{,}032^2 \cdot 0{,}785 = 0{,}090 \text{ м}^2;$$

the average/mean bundle of the second on the vapor step/stage

$$f_{2с} = 96 \cdot 0{,}032^2 \cdot 0{,}785 = 0{,}077 \text{ м}^2.$$

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Calculated clear opening for the pass of vapor

$$f_{ср} = \frac{957 + 797}{\frac{797}{0{,}137} + \frac{112}{208}\frac{957}{0{,}090} + \frac{96}{208}\frac{957}{0{,}077}} = 0{,}102 \text{ м}^2.$$

d) The second (on the course of water) step/stage of economizer (Fig. 15e).

Diameter of ducts 38X4.5 mm, run of pipes - checkered.

The heating surface is determined taking into account the fact that the part of the length of ccils is clcsed with antiwear sheets. In this case it is accepted that in the heat exchange participates only the half the surface of heating the clcsed sections.

The overall length cf ccils in the limits cf the flue

$$l = 4{,}700 \cdot 10 + 4{,}675 \cdot 4 + 3{,}14\,(0{,}075 \cdot 11 + 0{,}100 \cdot 2) + 2 \cdot 0{,}125 + 0{,}425 = 69{,}6\ \text{м}.$$

Lengths of the secticns cf ccils, closed with anti-wear sheets,

$$l_{закр} = 3{,}14\,(0{,}075 \cdot 11 + 0{,}100 \cdot 2) + 0{,}010 \cdot 14 + 0{,}020 \cdot 12 + 0{,}425 = 4{,}02\ \text{м}.$$

Calculated surface of heating the step/stage

$$H = \left(69{,}6 - \frac{4{,}0}{2}\right) 59 \cdot 2 \cdot 3{,}14 \cdot 0{,}038 = 952\ \text{м}^2.$$

Section/cut for the pass of gases is alsc determined taking into acccunt the coverage of the part cf the length cf flue by antiwear sheets. The calculated length of flue is accepted average/mean between the length of free frcm the sheets part and entire length of flue.

Calculated cross-secticn fcr the pass cf the gases

$$F = \left(9{,}900 - \frac{0{,}270 + 2 \cdot 0{,}116}{2}\right) 3{,}140 - 2 \cdot 4{,}670 \cdot 0{,}038\,\frac{59}{2} = 19{,}8\ \text{м}^2.$$

Spacings between tubes:

$$s_1 = 105\ \text{мм};\quad \frac{s_1}{d} = \frac{105}{38} = 2{,}77;$$

$$s_2 = 75\ \text{мм};\quad \frac{s_2}{d} = \frac{75}{38} = 1{,}97.$$

Number run of pipes on the course of gases - 28.

Efficient thickness of radiation layer within the limits of the team itself

$$s = [1,87(2,77+1,97)-4,1]\,0,038 = 0,181 \text{ м}.$$

Computed value of the efficient thickness of radiation layer with the radiation correction of the rotary chamber/camera with a height of 3.1 m [see formula (7.51)]

$$s' = 0,181\frac{2,02+0,2\cdot 3,1}{2,02} = 0,236 \text{ м},$$

where 2.02 m the height of the tube bank of economizer.

Section/cut for the pass of water (with 118 parallel connected coils)

$$f = 118\cdot 0,785\cdot 0,029^2 = 0,0779 \text{ м}^2.$$

e) air preheater (each of the steps/stages).

Two-pass by the air. Diameter of ducts 51X1.5 mm, run of pipes - checkered. It consists of eight sections. Quantities of the ducts

$$z = 8(15\cdot 28+14\cdot 26) = 6\,272.$$

Surface of heating air preheater (at the washed by air length of ducts l=5.552 m)

$$H = 3,14\cdot 0,0495\cdot 5,552\cdot 6\,272 = 5\,420 \text{ м}^2.$$

Section/cut for the pass ot the gases

$$F=0,785\cdot 0,048^2\cdot 6\,272=11,3\ м^2.$$

Section/cut for the pass ot the air

$$f=2\left(4,956-4\cdot\frac{29}{2}\cdot 0,051-3\cdot 0.06\right)2,772=$$
$$=10,1\ м^2.$$

Spacings between tubes:

$$s_1=80\ мм;\quad \frac{s_1}{d}=1,57;$$
$$s_2=55\ мм;\quad \frac{s_2}{d}=1,08.$$

A number of runs of pipes on the course of air (for calculation $a_к$ are considered the series/rows only of one course)

$$z_2=55.$$

f) first (on the course of water) stage of economizer.

Diameter of ducts 38X4.5 mm, run of pipes - checkered. Arrangement and sizes/dimensions of antiwear sheets the same as in the second step/stage. The determination of the surface of heating and section/cut for the pass of gases is conducted with the same assumptions.

The overall length of coils in the limits of the flue

$$l=4,900\cdot 18+4,875\cdot 10+3,14\,(0,075\cdot 22+$$
$$+0,100\cdot 5)+2\cdot 0,125+2\cdot 0,425=145\ м.$$

Length of the sections of coils, closed with antiwear sheets,

$$l_{закр}=3,14\,(0,075\cdot 22+0,100\cdot 5)+2\cdot 0,425+$$
$$+0,010\cdot 28+0,020\cdot 26=8,40\ м.$$

Calculated surface of heating the step/stage

$$H=\left(145-\frac{8}{2}\right)3,14\cdot 0,038\cdot 2\cdot 51=1\,720\ м^2.$$

Calculated cross-section for the pass of the gases

$$F=\left(10{,}300-\frac{0{,}270+2\cdot 0{,}116}{2}\right)2{,}720-$$
$$-2\cdot 4{,}870\cdot 0{,}038\frac{51}{2}=18{,}0\ м^2.$$

Spacings between tubes:

$$s_1=105\ мм;\quad \frac{s_1}{d}=\frac{105}{38}=2{,}77;$$

$$s_2=75\ мм;\quad \frac{s_2}{d}=\frac{75}{38}=1{,}97.$$

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Number of runs of pipes on the course of gases - 56.

Efficient thickness of radiation layer

$$s=[1{,}87\,(2{,}77+1{,}97)-4{,}1]\,0{,}038=0{,}181\ м.$$

Section/cut for the pass of water (with 102 in parallel connected coils)

$$f=102\cdot 0{,}785\cdot 0{,}029^2=0{,}0673\ м^2.$$

Fuel/propellant.

Withdrawals/departures of the enrichment of carbon/coals, brand PPM.

Calculated propellant composition (see ŔN 2-01):

(1) Влага $W^p = 11,0\%$
(2) Зола $A^p = 40,1\%$
(3) Сера $S^p_{л+к} = 3,8\%$
(4) Углерод $C^p = 38,6\%$
(5) Водород $H^p = 2,6\%$
(6) Азот $N^p = 0,8\%$
(7) Кислород $O^p = 3,1\%$
100%

Key: (1). Moisture. (2). Ash. (3). Sulfur. (4). Carbon. (5). Hydrogen. (6). Nitrogen. (7). Oxygen.

Fuel heating value $Q^p_н = 3650$ kcal/kg.

Output/yield of volatile components to combustible mass $V^г$ =30.0o/o.

Excess air ratios, volumes and enthalpy of combustion products in the flues.

The excess air ratio at the output/yield from burner

$\alpha_т$ =1.20 (it is accepted on RN 5-02).

The excess air ratios in other sections of the gas circuit are obtained by the method of addition to $\alpha_т$ the suctions of air, taken on RN 4-06.

Volumes and enthalpy of air and combustion products.

Since propellant composition is accepted tabular (on RN 2-01), volumes and enthalpy of air and products combustions are determined with the help of RN 4-02 and 4-05.

The results of calculation are reduced in Tables 1 and 2 (see RN 4-01).

Table 1. Average/mean characteristics of combustion products in the heating surfaces $A^p = 40,1\%$.

| (1) Наименование величин | (2) Размерность | $V^0 = 4,15$ нм³/кг; $V_{RO_2} = 0,75$ нм³/кг; $V^0_{N_2} = 3,28$ нм³/кг; $V^0_{H_2O} = 0,49$ нм³/кг | | | | | |
|---|---|---|---|---|---|---|---|
| | | (3) Топка и фестон | (4) Перегреватель | (5) Экономайзер II ступени | (6) Воздухоподогреватель II ступени | (7) Экономайзер I ступени | (8) Воздухоподогреватель I ступени |
| (9) Коэффициент избытка воздуха за газоходом α'' | — | 1,20 | 1,25 | 1,27 | 1,32 | 1,34 | 1,39 |
| (10) Коэффициент избытка воздуха средний α | — | 1,20 | 1,225 | 1,26 | 1,295 | 1,33 | 1,365 |
| $V_{H_2O} = V^0_{H_2O} + 0,0161\,(\alpha - 1)\,V^0$ | (11) нм³/кг | 0,503 | 0,505 | 0,508 | 0,509 | 0,512 | 0,514 |
| $V_г = V_{RO_2} + V^0_{N_2} + V_{H_2O} + (\alpha - 1)\,V^0$ | (11) нм³/кг | 5,36 | 5,47 | 5,62 | 5,76 | 5,91 | 6,06 |
| $r_{RO_2} = \frac{V_{RO_2}}{V_г}$ | — | 0,140 | 0,138 | 0,134 | 0,130 | 0,127 | 0,124 |
| $r_{H_2O} = \frac{V_{H_2O}}{V_г}$ | — | 0,094 | 0,0925 | 0,0905 | 0,0885 | 0,0865 | 0,085 |
| $r_п = r_{RO_2} + r_{H_2O}$ | — | 0,234 | 0,230 | 0,224 | 0,218 | 0,214 | 0,209 |
| $\mu = 10\,\frac{A^p a_{ун}}{V_г}$ | (12) г/нм³ | 67,0 | 65,7 | 64,0 | 62,5 | 61,0 | 59,5 |

Key: (1). Designation of values. (2). Dimensionality. (3). Heating and scallop. (4). Superheater. (5). Economizer of II step/stage. (6). Air preheater of II step/stage. (7). Economizer of I step/stage. (8). Air preheater of I step/stage. (9). Excess air ratio after flue α''. (10). Excess air ratio average/mean α. (11). nm³/kg. (12). g/nm³.

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Table 2 (iϑ- table). Enthalpy of combustion products.

| ϑ, °C | $I_г^0$, ккал/кг (1) | $I_в^0$, ккал/кг (1) | $(c\vartheta)_{зл}$, ккал/кг (1) | $I_{зл}=(c\vartheta)_{зл}\cdot a_{ун}\cdot\frac{A^р}{100}$, ккал/кг (1) | $I=I_г^0+(\alpha-1)\,I_в^0+I_{зл}$, ккал/кг (1) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $\alpha_т=\alpha''_ф=1{,}20$ | | $\alpha''_{пеII}=1{,}225$ | | $\alpha''_{пе}=1{,}25$ | | $\alpha''_{эк_2}=1{,}27$ | | $\alpha''_{вп_1}=1{,}32$ | | $\alpha''_{эк_1}=1{,}34$ | | $\alpha_{ух}=1{,}39$ | |
| | | | | | I | ΔI | I | ΔI | I | ΔI | I | ΔI | I | ΔI | I | ΔI | I | ΔI |
| 100 | 150 | 131 | 19,3 | 7,0 | | | | | | | | | | | | | 208 | 213 |
| 200 | 304 | 264 | 40,4 | 14,6 | | | | | | | | | 403 | 209 | 408 | 212 | 421 | |
| 300 | 462 | 399 | 63,0 | 22,8 | | | | | | | | | 612 | 215 | 620 | 217 | | |
| 400 | 624 | 536 | 86,0 | 31,0 | | | | | | | 800 | 214 | 827 | 221 | 837 | 224 | | |
| 500 | 792 | 677 | 109,5 | 39,5 | | | | | | | 1 014 | 219 | 1 048 | | 1 061 | | | |
| 600 | 963 | 821 | 133,8 | 48 | | | | | 1 216 | 223 | 1 233 | 225 | | | | | | |
| 700 | 1 140 | 969 | 158,2 | 57 | 1 391 | 218 | 1 415 | 222 | 1 439 | 226 | 1 458 | | | | | | | |
| 800 | 1 319 | 1 118 | 183,2 | 66 | 1 609 | 222 | 1 637 | 226 | 1 665 | 231 | | | | | | | | |
| 900 | 1 502 | 1 270 | 209 | 75 | 1 831 | 227 | 1 863 | | 1 896 | | | | | | | | | |
| 1 000 | 1 688 | 1 423 | 235 | 85 | 2 058 | 229 | | | | | | | | | | | | |
| 1 100 | 1 877 | 1 579 | 262 | 95 | 2 287 | 232 | | | | | | | | | | | | |
| 1 200 | 2 068 | 1 736 | 288 | 104 | 2 519 | | | | | | | | | | | | | |
| 1 600 | 2 850 | 2 379 | 448 | 162 | 3 488 | 247 | | | | | | | | | | | | |
| 1 700 | 3 050 | 2 542 | 493 | 178 | 3 735 | 245 | | | | | | | | | | | | |
| 1 800 | 3 250 | 2 705 | 522 | 189 | 3 980 | 497 | | | | | | | | | | | | |
| 2 000 | 3 654 | 3 035 | 600 | 216 | 4 477 | | | | | | | | | | | | | |

Key: (1). kcal/kg.

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| Наименование величины | Обозначение | Расчетная формула или способ определения | Размерность | Расчет |
|---|---|---|---|---|
| **Тепловой баланс и расход топлива** | | | | |
| Располагаемое тепло топлива | $Q_p^p$ | $Q_н^p$ | ккал/кг | 3 650 |
| Температура уходящих газов | $\vartheta_{ух}$ | Принята с последующим уточнением | °C | 160 |
| Теплосодержание уходящих газов | $I_{ух}$ | По $I\vartheta$-таблице | ккал/кг | 336 |
| Теплосодержание теоретически необходимого количества холодного воздуха[2] | $I^0_{х.в}$ | То же | » | 39,2 |
| Потеря тепла от механического недожога | $q_4$ | По РН 5-02 | % | 2,5 |
| Потеря тепла с уходящими газами | $q_2$ | $\frac{(I_{ух}-\alpha_{ух}\cdot I^0_{х.в})(100-q_4)}{Q_p^p}$ | % | $\frac{(336-1,39\cdot 39,2)}{3\,650}(100-2,5)=7,5$ |
| Потеря тепла от химического недожога | $q_3$ | По РН 5-02 | % | 0,5 |
| Потеря тепла в окружающую среду | $q_5$ | По графику РН 5-01 | % | 0,5 |
| Коэффициент сохранения тепла | $\varphi$ | $1-\frac{q_5}{100}$ | — | $1-\frac{0,5}{100}=0,995$ |
| Потеря с физическим теплом шлаков[3] | $q_{6шл}$ | $\frac{a_{шл}(ct)_{шл}A^p}{Q_p^p}$ | % | $\frac{0,1\cdot 134\cdot 40,1}{3\,650}=0,1$ |
| Сумма тепловых потерь | $\Sigma q$ | $q_2+q_3+q_4+q_5+q_{6шл}$ | % | $7,5+0,5+2,5+0,5+0,1=11,1$ |
| Коэффициент полезного действия агрегата | $\eta_{к.а}$ | $100-\Sigma q$ | % | $100-11,1=88,9$ |
| Теплосодержание перегретого пара | $i_{п.п}$ | По приложению II | ккал/кг | 813,1 |
| Теплосодержание питательной воды | $i_{п.в}$ | То же | | 220,6 |
| Полезно использованное в агрегате тепло[4] | $Q_{к.а}$ | $D(i_{п.п}-i_{п.в})$ | ккал/час | $230\,000\,(813,1-220,6)=136,3\cdot 10^6$ |
| Полный расход топлива | $B$ | $\frac{Q_{к.а}\,100}{Q_p^p\,\eta_{к.а}}$ | кг/час | $\frac{136,3\cdot 10^6\cdot 100}{3\,650\cdot 88,9}=42\,000$ |
| Расчетный расход топлива (действительно сгоревшего) | $B_p$ | $B\frac{100-q_4}{100}$ | » | $42\,000\left(\frac{100-2,5}{100}\right)=41\,000$ |
| **Расчет топки** | | | | |
| Объем топочной камеры | $V_т$ | По конструктивным характеристикам | м³ | 1 210 |
| Полная лучевоспринимающая поверхность нагрева | $H_л$ | То же | м² | 677 |
| Степень экранирования топки | $\psi$ | То же | — | 0,969 |

Key: (1). Designation cf value. (2). Designaticn. (3). Calculation formula or method of determinaticn. (4). Dimensicnality. (5). Calculation. (6). Heat balance and fuel consumpticn. (7). Available heat of fuel/propellant. (8). kcal/kg. (8a). kcal/h. (8b). kg/h. (8c). Temperature of departing gases. (9). It is accepted with subsequent refinement. (10). Enthalpy of stack gases. (11). Enthalpy cf theoretically necessary quantity of cold air [2].

FOOTNOTE [2]. In view of the absence of special indications it is accepted $t_{x.в}=30^\circ C$. ENDFOOTNOTE.

(12). Then. (13). Heat lcss from mechanical incomplete burning. (14). On RN 5-02. (15). Heat lcss with stack gases. (16). Heat loss from chemical incomplete burning. (17). Heat loss into envircnment. (18). On graph/curve RN 5-01. (19). Coefficient of the retention/preservation/maintaining heat. (20). Losses with physical heat of slags [3].

FOOTNOTE [3]. It is considered, since $A^p > \frac{Q_н^p}{100}$. ENDFOOTNOTE.

(21). Sum of heat losses. (22). Efficiency cf aggregate/unit. (23). Enthalpy of superheated steam. (24). On appendix II. (25). Enthalpy of feed water. (26). Usefully used in aggregate/unit heat [4].

FOOTNOTE [4]. The heat, returned tc blowoff water, is nct considered, since $\varepsilon_{np}$ <2o/o. ENDFCOTNCTE.

(27). Full rate cf propellant flcw. (28). Calculated consumption of fuel (actually/really turned down). (29). Calculaticn of heating. (30). Volume of furnace chamber/camera. (30a). According to the structural/design characteristics. (31). Full/tctal/complete beam-receiving heating surface. (32). Degree cf shielding of burner.

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FOOTNOTE [1]. Since $w_{P} < \frac{Q^{P}_{H}}{150}$, the heat cf fuel/prcpellant is not considered. ENDFOOTNOTE.

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Continued.

| (1) Наименование величины | Обо(2) значение | Расчетная формула или(3) способ определения | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| (6) Поправочный коэффициент | $\beta$ | РН 6-02 | — | 0,65 |
| (7) Эффективная степень черноты факела | $a_\phi$ | $\beta a$ | — | $0{,}65 \cdot 1{,}0 = 0{,}65$ |
| (8) Условный коэффициент загрязнения | $\zeta$ | (9) По РН 6-02 | — | 0,7 |
| (10) Степень черноты топки | $a_m$ | (11) То же | — | 0,60 |
| (12) Коэффициент избытка воздуха в топке | $\alpha_m$ | (9) По РН 5-02 | — | 1,20 |
| (13) Температура горячего воздуха | $t_{г.в}$ | (14) Принимается с последующим уточнением | °C | 345 |
| (15) Присос воздуха в топку | $\Delta\alpha_m$ | (9) По РН 4-06 | — | 0,1 |
| (16) Присос воздуха в систему пылеприготовления[1] | $\Delta\alpha_{пл.у}$ | (9) По РН 4-07 | — | 0,07 |
| (17) Отношение количества воздуха на выходе из воздухоподогревателя к теоретически необходимому | $\beta''_{вп}$ | $\alpha_m - \Delta\alpha_m - \Delta\alpha_{пл.у}$ | — | $1{,}2 - 0{,}1 - 0{,}07 = 1{,}03$ |
| (18) Теплосодержание теоретически необходимого горячего воздуха при принятой $t_{г.в}$ | $I^0_{г.в}$ | (19) По $I\vartheta$-таблице | (20) ккал/кг | 461 |
| (21) То же холодного воздуха | $I^0_{х.в}$ | (11) То же | » | 39,2 |
| (22) Тепло, вносимое воздухом в топку | $Q_в$ | $\beta''_{вп} \cdot I^0_{г.в} + (\Delta\alpha_m + \Delta\alpha_{пл.у}) I^0_{х.в}$ | » | $1{,}03 \cdot 461 + (0{,}1 + 0{,}07)\, 39{,}2 = 482$ |
| (23) Тепловыделение в топке на 1 кг топлива | $Q_m$ | $Q^p_p \frac{100 - q_3}{100} + Q_в$ | » | $3\,650 \frac{100 - 0{,}5}{100} + 482 = 4\,112$ |
| (24) Теоретическая температура горения | $\vartheta_a$ | По $I\vartheta$-таблице[2] (19) | °C | 1 858 |
| (25) Тепловыделение на 1 м² поверхности нагрева | — | $\frac{B_p Q_m}{\zeta H_л}$ | (26) ккал/м²час | $\frac{41\,000 \cdot 4\,112}{0{,}7 \cdot 677} = 356 \cdot 10^3$ |
| (27) Температура газов на выходе из топки | $\vartheta''_m$ | (28) По номограмме I | °C | 1 117[5] |
| (29) Теплосодержание газов на выходе из топки[3] | $I''_m$ | (19) По $I\vartheta$-таблице | (20) ккал/кг | 2 326 |
| (31) Тепло, переданное излучением в топке | $Q_л$ | $\varphi\,(Q_m - I''_m)$ | » | $(4\,112 - 2\,326)\, 0{,}995 = 1\,780$ |
| (32) Тепловая нагрузка лучевоспринимающей поверхности нагрева | — | $\frac{B_p Q_л}{H_л}$ | (26) ккал/м²час | $\frac{41\,000 \cdot 1\,780}{677} = 108 \cdot 10^3$ |
| (33) Видимое теплонапряжение топочного объема[4] | — | $\frac{B_p Q^p_н}{V_m}$ | (26) ккал/м³час | $\frac{41\,000 \cdot 3\,650}{1\,210} = 124 \cdot 10^3$ |

Key: (1). Designation of value. (2). Designation. (3). Calculation formula or method of determination. (4). Dimensionality. (5). Calculation. (6). Correction factor. (7). Efficient emissivity factor of flame. (8). Conditional coefficient of pollution/contamination. (9). On RN 6-02. (10). Degree of blackening of fuel. (11). The same. (12). Excess air ratio in heating. (13). Temperature of hot air. (14). It is accepted with subsequent refinement. (15). Suction of air into heating. (16). Suction of air into system of pulverized coal preparation [1].

FOOTNOTE [1]. Individual diagram with the dust hopper. ENDFOOTNOTE.

(17). Relation of quantity of air at output/yield. (18). Heat content of theoretically necessary hot air with that accepted t... (19). On i9-table. (20). kcal/kg. (21). Then of cold air. (22). Heat, introduced by air into heating. (23). Heat release in heating on 1 kg of fuel/propellant. (24). Theoretical combustion temperature. (25). Heat release to 1 $m^2$ of heating surface. (26). kcal/$m^2$h. (27). Temperature of gases at output/yield from heating. (28). On nomogram I. (29). Enthalpy of gases at output/yield from heating [3].

FOOTNOTE [3]. On ... and ... ENDFOOTNOTE.

(30). No Key. (31). Heat, transmitted by radiation/emission in

heating. (32). Thermal load of beam-receiving heating surface. (33). Seen thermal stress of furnace cavity [1].

FOOTNOTE [1]. It lies/rests within the limits of the recommended with SN 5-02 values. ENDFOOTNOTE.

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FOOTNOTE [2]. In value $q_m$ when $\cdot_m$. ENDFOOTNOTE.

FOOTNOTE [3]. Excess of the recommended limit insignificantly and can be allowed. ENDFOOTNOTE.

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Continued.

| (1) Наименование величины | (2) Обозначение | (3) Расчетная формула или способ определения | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| | | (6) **Расчет фестона** | | |
| (7) Полная поверхность нагрева | $H$ | (8) По конструктивным характеристикам | $м^2$ | 150 |
| (9) Лучевоспринимающая поверхность фестона | $H_{л.п}$ | (10) То же | » | 42,6 |
| (11) Диаметр труб | $d$ | » » | *мм* | 76×6 |
| (12) Относительный шаг поперечный | $s_1/d$ | » » | — | 5,0 |
| (13) Относительный шаг продольный | $s_2/d$ | » » | — | 3,95 |
| (14) Число рядов труб по ходу газов | $z_2$ | » » | — | 4 |
| (15) Живое сечение для прохода газов | $F$ | » » | $м^2$ | 47,2 |
| (16) Эффективная толщина излучающего слоя | $s$ | » » | *м* | 1,11 |
| (17) Расчетная поверхность нагрева | $H_р$ | $H-H_{л.п}$ | $м^2$ | 107,4 |
| (18) Температура газов перед фестоном | $\vartheta'$ | (19) Из расчета топки | °C | 1 117 |
| (20) Теплосодержание газов перед фестоном | $I'$ | (10) То же | (21) *ккал/кг* | 2 326 |
| (22) Температура газов за фестоном | $\vartheta''$ | (23) *Принимается с последующим уточнением* | °C | 1 080 |
| (24) Теплосодержание газов за фестоном при $\alpha''_ф=\alpha_т$ | $I''$ | (25) По $I\vartheta$-таблице | (21) *ккал/кг* | 2 241 |
| (26) Тепловосприятие фестона (по балансу) | $Q_б$ | $\varphi(I'-I'')$ | » » | 0,995 (2 326—2 241)=84,5 |
| (27) Температура кипения при давлении в барабане котла $p_б=110$ *ата* | $t_{кип}$ | (28) По приложению II | °C | 317 |
| (29) Средняя температура газов | $\vartheta$ | $\frac{\vartheta'+\vartheta''}{2}$ | °C | $\frac{1\,117+1\,080}{2}=1\,098$ |
| (30) Средний температурный напор[1] | $\Delta t$ | $\vartheta-t_{кип}$ | °C | 1 098—317=781 |
| (31) Объем газов на 1 *кг* топлива при $\alpha=1{,}20$ | $V_г$ | (32) По табл. 1 | (33) $нм^3/кг$ | 5,36 |
| (34) Объемная доля $H_2O$ | $r_{H_2O}$ | (10) То же | — | 0,094 |
| (35) Объемная доля трехатомных газов | $r_п$ | » » | — | 0,234 |
| (36) Концентрация золы | $\mu$ | » » | (37) $г/нм^3$ | 67,0 |
| (38) Средняя скорость газов в фестоне | $w$ | $\frac{B_р}{3\,600}\cdot\frac{V_г}{F}\cdot\frac{\vartheta+273}{273}$ | (39) *м/сек* | $\frac{41\,000\cdot5{,}36\,(1\,098+273)}{3\,600\cdot47{,}2\cdot273}=6{,}5$ |
| (40) Коэффициент теплоотдачи конвекцией | $\alpha_к$ | (41) По номограмме III | (42) $\frac{ккал}{м^2\,час\,град}$ | 39,0 |
| (43) Коэффициент загрязнения | $\varepsilon$ | (41) По номограмме XII | (44) $\frac{м^2\,час\,град}{ккал}$ | 0,0058·2,0·1,0+0,002=0,0136 |
| (45) Суммарная поглощательная способность трехатомных газов | $p_п s$ | $r_п s$ | *м ата* (46) | 0,234·1,11=0,260 |

Key: (1). Designation of value. (2). Designation. (3). Calculation formula or method of determination. (4). Dimensionality. (5). Calculation. (6). Calculation of scallop. (7). Full/total/complete heating surface. (8). According to structural/design characteristics. (9). Beam-receiving surface of scallop. (10). The same. (11). Diameter of ducts. (12). Relative step/pitch transverse. (13). Relative step/pitch longitudinal. (14). Number of runs of pipes on course of gases. (15). Clear opening for pass of gases. (16). Efficient thickness of radiation layer. (17). Calculated heating surface. (18). Temperature of gases before festoon. (19). From calculation of heating. (20). Enthalpy of gases before scallop. (21). kcal/kg. (22). Temperature of gases after scallop. (23). It is accepted with subsequent refinement. (24). Enthalpy of gases after scallop when $\alpha''_{\phi} = \alpha_m$ (25). On is-table. (26). Heat absorption of scallop (on balance). (27). Boiling point at pressure in boiler barrel $p_б$=110 atm(abs.). (28). On appendix II. (29). Mean temperature of gases. (30). Average/mean temperature head [1].

FOOTNOTE [1]. In scallops $\frac{\Delta t_б}{\Delta t_м}$ it is always less than 1.7 and calculation Δt always can be conducted according to a mean arithmetic difference in the temperatures. ENDFOOTNOTE.

(31). Volume of gases on 1 kg of fuel/propellant with α=1.20. (32).

On Tables 1. (33). $nm^3/kg$. (34). Volume fraction $H_2O$. (35). Volume fraction of triatomic gases. (36). Ash concentration. (37). $g/nm^3$. (38). Average/mean gas velocity in scallop. (39). m/s. (40). Convection heat-transfer coefficient. (41). On nomogram. (42). kcal/$m^2$ hour deg. (43). Contamination factor. (44). $m^2$ hour deg/kcal. (45). Total absorptivity of triatomic gases. (46). m atm(abs.).

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Continued.

| (1) Наименование величины | (2) Обозначение | (3) Расчетная формула или способ определения | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| (6) Коэффициент ослабления лучей трехатомными газами | $k_г$ | (7) По номограмме IX | — | 0,90 |
| (8) Коэффициент ослабления лучей золовыми частицами | $k_п$ | (7) По номограмме X | — | 0,0102 |
| (9) Сила поглощения запыленным потоком[1] | $kps$ | $(k_г r_п + k_п \mu) ps$ | — | $(0,9 \cdot 0,234 + 0,0102 \cdot 67) \times$ $\times 1,11 = 0,99$ |
| (10) Температура загрязненной стенки труб | $t_з$ | $t_к + \frac{Q_б B_p}{H_ф} \varepsilon$ | °C | $317 + \frac{84,5 \cdot 41\,000}{107,4} 0,0136 =$ $= 755$ |
| (11) Коэффициент теплоотдачи излучением запыленного потока | $\alpha_л$ | (7) По номограмме XI | (12) $\frac{ккал}{м^2 час\ град}$ | 205 |
| (13) Коэффициент теплопередачи | $k$ | $\frac{\alpha_к + \alpha_л}{1 + \varepsilon(\alpha_к + \alpha_л)}$ | (12) $\frac{ккал}{м^2 час\ град}$ | $\frac{39,0 + 205}{1 + 0,0136\ (39,0 + 205)} =$ $= 56,5$ |
| (14) Тепловосприятие фестона (по уравнению теплообмена) | $Q_т$ | $\frac{kH_p \Delta t}{B_p}$ | (15) ккал/кг | $\frac{56,5 \cdot 107,4 \cdot 781}{41\,000} = 116$ |
| (16) Отношение расчетных величин тепловосприятия | — | $\frac{Q_{тI}}{Q_{бI}} \cdot 100$ | % | $\frac{116}{84,5} \cdot 100 = 137$ |

(17) Так как значения $Q_т$ и $Q_б$ разнятся больше чем на 5% (допустимое расхождение для фестонов), необходимо уточнить расчет (см. п. 8-04). Для этого принимается новое значение температуры газов за фестоном.

| | | | | |
|---|---|---|---|---|
| (18) Температура газов за фестоном[2] | $\vartheta''$ | (19) Принята | °C | 1 066 |
| (20) Теплосодержание газов за фестоном | $I''$ | (21) По $I\vartheta$-таблице | (15) ккал/кг | 2 209 |
| (23) Тепловосприятие фестона (по балансу) | $Q_{бII}$ | $\varphi (I' - I'')$ | — | $0,995\ (2\,326 - 2\,209) = 116$ |
| (24) Средняя температура газов | $\vartheta$ | $\frac{\vartheta' + \vartheta''}{2}$ | °C | $\frac{1\,117 + 1\,066}{2} = 1\,091$ |
| (25) Средний температурный напор | $\Delta t$ | $\vartheta - t_{кип}$ | °C | $1\,091 - 317 = 774$ |
| (26) Тепловосприятие фестона (по уравнению теплообмена)[3] | $Q_{тII}$ | $\frac{kH_p \cdot \Delta t}{B_p}$ | (15) ккал/кг | $\frac{56,5 \cdot 107,4 \cdot 774}{41\,000} = 115$ |
| (27) Отношение расчетных величин тепловосприятия | — | $\frac{Q_{тII}}{Q_{бII}} \cdot 100$ | % | $\frac{115}{116} \cdot 100 = 99$ |

(28) В этот раз значения $Q_т$ и $Q_б$ разнятся меньше чем на 5%, и поэтому пересчет не производится.

Key: (1). Designation of value. (2). Designation. (3). Calculation formula or method of determination. (4). Dimensionality. (5). Calculation. (6). Coefficient of weakening rays/beams by triatomic gases. (7). On nomogram. (8). Coefficient of weakening rays/beams by ash particles. (9). Absorption strength by dusty flow [1].

FOOTNOTE [1]. Total pressure in the heating p=1 atm(abs.); therefore subsequently factor p in the formulas is absent. ENDFOOTNOTE.

(10). Temperature of contaminated wall of ducts. (11). Radiation heat-transfer coefficient of dusty flow. (12). kcal/m² hour deg. (13). Coefficient of heat transfer. (14). Heat absorption of scallop (according to equation of heat exchange). (15). kcal/kg. (16). Relation of calculated values of heat absorption. (17). Since value $Q_m$ and $Q_6$ it is separated more than for 5o/o (permissible disagreement for festoons ), it is necessary to make more precise calculation (see Section 8-C4). For this is accepted the new value of the temperature of gases after the festoon. (18). Temperature of gases after festoon [2].

FOOTNOTE [2]. Since $Q_{m1}>Q_{61}$, $\vartheta''$ in the second approximation/approach is accepted smaller than in the first. ENDFOOTNOTE.

(19). It is accepted. (20). Enthalpy of gases after scallop [festoon] (21). On is-table. (22). No Key. (23). Heat absorption of scallop (on balance). (24). Mean temperature of gases. (25). Average/mean temperature of smoke. (26). Heat absorption of scallop (according to equation of heat exchange) [3].

FOOTNOTE [3]. Value k is accepted according to the first calculation, since the difference between both values ''$\vartheta$<50°C ACCEPTED. ENDFOOTNOTE.

(27). Relation of calculated values of heat absorption. (28). This time of value $Q_m$ and $Q_б$ it is separated less than for 5o/o and therefore recalculation is not produced.

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Continued.

*Продолжение*

| (1) Наименование величины | (2) Обозначение | (3) Расчетная формула или способ определения | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| | | (6) **Расчет перегревателя** | | |
| (7) Средний диаметр труб | $d_{cp}$ | (8) По конструктивным характеристикам | мм | 40 |
| (9) Среднее живое сечение для прохода газов | $F_{cp}$ | То же (10) | м² | 30,4 |
| (11) Эффективная толщина излучающего слоя | $s'$ | » » | м | 0,301 |
| (12) Число рядов труб | $z_2$ | » » | — | 30 |
| (13) Поверхность нагрева первой части (по ходу пара) | $H_I$ | » » | м² | 797 |
| (14) То же второй части | $H_{II}$ | » » | м² | 957 |
| (15) Среднее живое сечение для прохода пара | $f_{cp}$ | » » | м² | 0,102 |
| (16) Угловой коэффициент фестона | $x_ф$ | » » | — | 0,746 |
| (17) Лучевоспринимающая поверхность фестона | $H_{л.ф}$ | » » | м² | 57,1 |
| (18) Тепловосприятие перегревателя излучением из топки[1] | $Q_л$ | $\frac{B_p Q_л}{H_л}\,\frac{H_{л.ф}}{B_p}\,(1-x_ф)\,y$ | (19) ккал/кг | $108\cdot 10^3\,\frac{57,1}{41\,000}\times$ $\times 0,254\cdot 0,75=29$ |
| (20) Температура газов на входе в поверхность | $\vartheta'$ | Из расчета фестона | °С | 1 066 |
| (21) Теплосодержание газов на входе | $I'$ | То же (10) | (19) ккал/кг | 2 209 |
| (22) Температура перегретого пара | $t_{п.п}$ | По заданию (23) | °С | 510 |
| (24) Теплосодержание пара | $i_{п.п}$ | (25) По приложению II | (19) ккал/кг | 813,1 |
| (26) Величина увлажнения пара в пароохладителе | $(1-x)\times$ $\times 100$ | (27) Принимается с последующим уточнением | % | 5,0 |
| (28) Теплота парообразования | $r$ | (29) По приложению II | (19) ккал/кг | 302,9 |
| (30) Тепло, переданное в пароохладителе | $\Delta i_{по}$ | $r\,(1-x)$ | » | 15,1 |
| (31) Теплосодержание насыщенного пара | $i_{н.п}$ | (32) По приложению II | » | 647,1 |
| (33) Тепловосприятие перегревателя (по балансу) | $Q_б$ | $(i_{п.п}-i_{н.п}+\Delta i_{по})\,\frac{D}{B_p}-$ $-Q_л$ | » | $(813,1-647,1+15,1)\times$ $\times\frac{230\,000}{41\,000}-29=986$ |
| (34) Теплосодержание газов за перегревателем | $I''$ | $I'-\frac{Q_б}{\varphi}+\Delta\alpha_{пе}\cdot I^0_{х.в}$ | » | $2\,209-\frac{986}{0,995}+$ $+0,05\cdot 39,2=1\,220$ |
| (35) Температура газов за перегревателем | $\vartheta''$ | По $I\vartheta$-таблице (36) | °С | 601 |
| (37) Средняя температура газов | $\vartheta$ | $\frac{\vartheta'+\vartheta''}{2}$ | °С | $\frac{1\,066+601}{2}=833$ |
| (38) Средняя температура пара | $t$ | (40) $\frac{t_{н.п}+t_{п.п}}{2}$ | °С | 414 |
| (39) Объем газов на 1 кг топлива | $V_г$ | По табл. 1 при $\alpha=$ $=1,225$ | нм³/кг (41) | 5,47 |

Key: (1). Designation cf value. (2). Designation. (3). Calculation formula or method of determination. (4). Dimensionality. (5). Calculation. (6). Calculaticn of superheater. (7). Mean diameter of ducts. (8). According tc structural/design characteristics. (9). Middle clear opening fcr pass ct gases. (10). Then. (11). Efficient thickness of radiaticn layer. (12). Number cf runs cf pipes. (13). Surface of heating first part (cn course cf vapcr). (14). Then of second part. (15). Middle clear opening for pass cf vapor. (16). Angular coefficient cf scallop. (17). Beam-receiving surface of scallop. (18). Heat absorption of superheater by radiation/emissicn from heating [1].

FOOTNOTE [1]. Value $\frac{B_p Q_l}{H_A}$ is accepted from the calculation of heating. ENDFOOTNOTE.

(19). kcal/kg. (20). Temperature cf gases at entrance into surface. (21). Enthalpy of gases at entrance. (22). Temperature of superheated steam. (23). On building. (24). Enthalpy of steam. (25). On appendix. (26). Value of moistening vapor in steam cccler. (27). It is accepted with subsequent refinement. (28). Heat of steam fcrmation. (29). Cn appendix. (30). Heat, transmitted in steam cccler. (31). Enthalpy of saturated steam. (32). Cn appendix. (33). Heat absorption of superheater (on balance). (34). Enthalpy of gases after superheater.

(35). Temperature of gases after superheater. (36). On i-d-table.
(37). Mean temperature of gases. (38). Mean temperature of steam.
(39). Volume of gases on 1 kg of fuel/propellant. (40). On Tables 1 with $\alpha$=1.225. (41). $nm^3$/kg.

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Continued.

| (1) Наименование величины | (2) Обозначение | (3) Расчетная формула или способ определения | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| (6) Объемная доля водяных паров | $r_{H_2O}$ | (7) По табл. 1 при $\alpha = 1{,}225$ | — | 0,092 |
| (8) Объемная доля трехатомных газов | $r_n$ | То же (9) | — | 0,23 |
| (10) Концентрация золы в дымовых газах | $\mu$ | „ „ | (11) $г/н.м^3$ | 65,7 |
| (12) Средняя скорость газов в перегревателе | $w$ | $\frac{B_p V_г}{F\ 3600} \frac{\vartheta+273}{273}$ | (13) $м/сек$ | $\frac{41\,000 \cdot 5{,}47\ (833+273)}{30{,}4 \cdot 3\,600 \cdot 273} = 8{,}3$ |
| (14) Коэффициент теплоотдачи конвекцией | $\alpha_к$ | (15) По номограмме II | (16) $\frac{ккал}{м^2\ час\ град}$ | 52,0 |
| (17) Коэффициент загрязнения | $\varepsilon$ | (15) По номограмме XII | $\frac{м^2\ час\ град}{ккал}$ (18) | $0{,}0075 \cdot 1{,}1 \cdot 1{,}0 + 0{,}002 = 0{,}0102$ |
| (19) Объем пара при средней температуре[1] | $v_n$ | (20) По приложению II | $м^3/кг$ (21) | 0,0265 |
| (22) Средняя скорость пара | $w_n$ | $\frac{D}{(5)\ 3600} \frac{v_n}{f_{cp}}$ | (13) $м/сек$ | $\frac{230\,000 \cdot 0{,}0265}{3\,600 \cdot 0{,}102} = 16{,}6$ |
| (23) Коэффициент теплоотдачи от стенки к пару | $\alpha_2$ | По номограмме V | $\frac{ккал}{м^2 час\ град}$ (16) | 2 450 |
| (24) Температура стенки перегревателя | $t_з$ | $t + \left(\varepsilon + \frac{1}{\alpha_2}\right) \frac{Q_б B_p}{H_I + H_{II}}$ | °C | $414 + (0{,}0102 + 0{,}0004) \times \frac{986 \cdot 41\,000}{797 + 957} = 658$ |
| (25) Суммарная поглощательная способность трехатомных газов | $p_n s$ | $r_n s'$ | (26) ата | $0{,}230 \cdot 0{,}301 = 0{,}069$ |
| (27) Коэффициент ослабления лучей трехатомными газами | $k_г$ | (5) По номограмме IX | — | 2,1 |
| (28) Коэффициент ослабления лучей золовыми частицами | $k_n$ | (5) По номограмме X | — | 0,0118 |
| (29) Сила поглощения запыленного потока | $ks$ | $(k_г \cdot r_n + k_n \mu)\ s'$ | — | $(2{,}1 \cdot 0{,}23 + 0{,}0118 \times 65{,}7)\ 0{,}301 = 0{,}378$ |
| (30) Коэффициент теплоотдачи излучением | $\alpha_л$ | (15) По номограмме XI | $\frac{ккал}{м^2\ час\ град}$ (16) | 60,6 |
| (31) Коэффициент теплопередачи в перегревателе | $k$ | $\frac{\alpha_к + \alpha_л}{1 + \left(\varepsilon + \frac{1}{\alpha_2}\right)(\alpha_к + \alpha_л)}$ | „ | $\frac{52{,}0 + 60{,}6}{1 + \left(0{,}0102 + \frac{1}{2450}\right)(52{,}0 + 60{,}6)} = 51{,}4$ |
| (32) Температурный напор на входе газов при противотоке | $\Delta t'_{прт}$ | $\vartheta' - t_{п.п}$ | °C | $1\,066 - 510 = 556$ |
| (33) То же на выходе | $\Delta t''_{прт}$ | $\vartheta'' - t_{н.п}$ | °C | $601 - 317 = 284$ |
| (34) Температурный напор при противотоке | $\Delta t_{прт}$ | $\frac{\Delta t'_{прт} - \Delta t''_{прт}}{2{,}3 \lg \frac{\Delta t'_{прт}}{\Delta t''_{прт}}}$ | °C | $\frac{556 - 284}{2{,}3 \lg \frac{556}{284}} = 404$ |
| (35) Температурный напор на входе газов при прямотоке | $\Delta t'_{прм}$ | $\vartheta' - t_{н.п}$ | °C | $1\,066 - 317 = 749$ |
| (33) То же на выходе | $\Delta t''_{прм}$ | $\vartheta'' - t_{п.п}$ | °C | $601 - 510 = 91$ |
| (36) Температурный напор при прямотоке | $\Delta t_{прм}$ | $\frac{\Delta t'_{прм} - \Delta t''_{прм}}{2{,}3 \lg \frac{\Delta t'_{прм}}{\Delta t''_{прм}}}$ | °C | $\frac{749 - 91}{2{,}3 \lg \frac{749}{91}} = 313$ |

Key: (1). Designation of value. (2). Designation. (3). Calculation formula or method of determination. (4). Dimensionality. (5). Calculation. (6). Volume fraction of water vapors. (7). On Tables 1 with. (8). Volume fraction of triatomic gases. (9). Then. (10). Ash concentration in flue gases. (11). g/nm³. (12). Average/mean gas velocity in superheater. (13). m/s. (14). Convection heat-transfer coefficient. (15). On nomogram. (16). kcal/m² hour deg. (17). Contamination factor. (18). m² hour deg/kcal. (19). Volume of steam at mean temperature [1].

FOOTNOTE [1]. According to mean temperature, rounded to the nearest smaller value, multiple of 10°C. ENDFOOTNOTE (20). On appendix. (21). m³/kg. (22). Average speed of steam. (23). Heat-transfer coefficient from wall to vapor. (24). Temperature of wall of superheater. (25). Total absorptivity of triatomic gases. (26). m atm(abs.). (27). Coefficient of weakening rays/beams by triatomic gases. (28). Coefficient of weakening rays/beams by ash particles. (29). Absorption strength of dusty flow. (30). Coefficient of heat emission by radiation/emission. (31). Coefficient of heat transfer in superheater. (32). Temperature head at entrance of gases with countercurrent. (33). Then at output/yield. (34). Temperature head with countercurrent. (35). Temperature head at yield of gases with direct flow. (36). Temperature head with direct flow.

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Continued.

*Продолжение*

| (1) Наименование величины | (2) Обозначение | (3) Расчетная формула или способ определения | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| (6) Отношение температурных напоров | $\frac{\Delta t_{прм}}{\Delta t_{прт}}$ | $\frac{\Delta t_{прм}}{\Delta t_{прт}}$ | — | $\frac{313}{404}=0{,}78$ |

(7) Так как отношение $\frac{\Delta t_{прм}}{\Delta t_{прт}}<0{,}92$, температурные напоры для обеих ступеней перегревателя приходится рассчитывать раздельно

(8) Расчет второй (по пару) ступени

| | | | | |
|---|---|---|---|---|
| (9) Температура газов на входе во вторую ступень | $\vartheta'$ | (10) Из расчета фестона | °C | 1 066 |
| (11) Теплосодержание газов на входе | $I'$ | (12) То же | (13) ккал/кг | 2 209 |
| (14) Температура газов на выходе из второй ступени | $\vartheta''$ | (15) Принимается с последующим уточнением | °C | 785 |
| (16) Теплосодержание газов на выходе | $I''$ | (17) По $I\vartheta$-таблице | (13) ккал/кг | 1 603 |
| (18) Тепловосприятие ступени по балансу | $Q_б$ | $\varphi\left(I'-I''+\frac{\Delta a_{пе}}{2}I^0_{х.в}\right)$ | » | 0,995 (2 209—1 603+1)=<br>=604 |
| (19) Теплосодержание пара на входе во вторую ступень ($p$=105 *ата*) | $i'$ | $i_{п.п}-(Q_б+Q_л)\frac{B_p}{D}$ | » | $813{,}1-(604+29)\frac{41\,000}{230\,000}=$<br>=700,5 |
| (20) Температура пара на входе | $t'$ | (21) По приложению II | °C | 355 |
| (22) Температурный напор на входе газов | $\Delta t'$ | $\vartheta'-t_{п.п}$ | °C | 1 066—510=556 |
| (23) Температурный напор на выходе газов | $\Delta t''$ | $\vartheta''-t'$ | °C | 785—355=430 |
| (24) Средний температурный напор при противотоке | $\Delta t_{прт}$ | $\frac{\Delta t'+\Delta t''}{2}$ | °C | $\frac{556+430}{2}=493$ |
| (25) Параметр | $P$ | $\frac{t_{п.п}-t'}{\vartheta'-t'}$ | — | $\frac{510-355}{1\,066-355}=0{,}218$ |
| (25) Параметр | $R$ | $\frac{\vartheta'-\vartheta''}{t_{п.п}-t'}$ | — | $\frac{1\,066-785}{510-355}=1{,}81$ |
| (26) Коэффициент | $\psi$ | (27) По номограмме XIV, кривая *I* | — | 0,95 |
| (28) Температурный напор во второй ступени | $\Delta t$ | $\psi\Delta t_{прт}$ | °C | 0,95·493=468 |
| (29) Тепловосприятие ступени по уравнению теплообмена | $Q_т$ | $\frac{kH_{II}\Delta t}{B_p}$ | (13) ккал/кг | $\frac{51{,}4\cdot957\cdot468}{41\,000}=561$ |

(30) Так как значения $Q_б$ и $Q_т$ разнятся более чем на 2%, расчет повторяется на вновь принимаемое значение $\vartheta''$

| | | | | |
|---|---|---|---|---|
| (31) Температура газов на выходе из второй ступени | $\vartheta''$ | (15) Принимается с последующим уточнением | °C | 805 |
| (16) Теплосодержание газов на выходе | $I''$ | (17) По $I\vartheta$-таблице | (13) ккал/кг | 1 648 |

Key: (1). Designation cf value. (2). Designaticn. (3). Calculation formula or method of determinaticn. (4). Dimersionality. (5). Calculation. (6). Relaticn of temperature heads. (7). Since ratio $\frac{\Delta t_{нбм}}{\Delta t_{npm}}$ <0.92, temperature heads for both steps/stages of superheater it is necessary to design separately. (8). Calculaticn of seccnd (cn vapor) step/stage. (9). Inlet temperature intc second step/stage. (10). From calculaticn cf scallop. (11). Enthalpy of gases at entrance. (12). Then. (13). kcal/kg. (14). Temperature of gases at cutput/yield from second step/stage. (15). It is accepted with subsequent refinement. (16). Enthalpy of gases at output/yield. (17). On iϑ-table. (18). Heat absorpticn of step/stage on balance. (19). Enthalpy of steam at output/yield into second step/stage (p=105 atm(abs.)). (20). Temperature cf steam at entrance. (21). On appendix. (22). Temperature head at entrance cf gases. (23). Temperature head at exit cf gases. (24). Average/mean temperature head with countercurrent. (25). Parameter. (26). Coefficient. (27). Cn nomogram. (28). Temperature head in second step/stage. (29). Heat absorption of step/stage according to equaticn of heat exchange. (30). Since value $Q_б$ and $Q_т$ it is separated fcr more than 2o/c, calculation is repeated at newly adopted value ϑ''. (31). Temperature of gases at output/yield frcm seccrd step/stage.

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Continued.

| (1) Наименование величины | (2) Обозначение | (3) Расчетная формула или способ определения | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| (6) Тепловосприятие ступени по балансу | $Q_б$ | $\varphi\left(I'-I''+\frac{\Delta\alpha_{пе}}{2}I^0_{х.в}\right)$ | (7) ккал/кг | $0,995\,(2\,209-1\,648+1)=560$ |
| (8) Теплосодержание пара на входе во вторую ступень | $i'$ | $i_{п.п}-(Q_б+Q_л)\frac{B_p}{D}$ | " | $813,1-(560+29)\frac{41\,000}{230\,000}=708,3$ |
| (9) Температура пара на входе | $t'$ | (10) По приложению II | °C | 364 |
| (11) Температурный напор на входе газов | $\Delta t'$ | $\vartheta'-t_{п.п}$ | °C | $1\,066-510=556$ |
| (12) Температурный напор на выходе газов | $\Delta t''$ | $\vartheta''-t'$ | °C | $805-364=441$ |
| (13) Средний температурный напор при противотоке | $\Delta t_{прт}$ | $\frac{\Delta t'+\Delta t''}{2}$ | °C | $\frac{556+441}{2}=498$ |
| (14) Параметр | $P$ | $\frac{t_{п.п}-t'}{\vartheta'-t'}$ | — | $\frac{510-364}{1\,066-364}=0,208$ |
| (14) Параметр | $R$ | (16) $\frac{\vartheta'-\vartheta''}{t_{п.п}-t'}$ | — | $\frac{1\,066-805}{510-364}=1,79$ |
| (15) Коэффициент | $\psi$ | По номограмме XIV | — | 0,96 |
| (17) Температурный напор во второй ступени | $\Delta t$ | $\psi\Delta t_{прт}$ | °C | $0,96\cdot498=478$ |
| (18) Тепловосприятие ступени по уравнению теплообмена | $Q_т$ | $\frac{kH_{II}\Delta t}{B_p}$ | (7) ккал/кг | $\frac{51,4\cdot957\cdot478}{41\,000}=574$ |

(19) Так как и в этот раз значения $Q_т$ и $Q_б$ разнятся больше чем на 2%, расчетное значение $\vartheta''_р$ определяется интерполяцией

| | | | | |
|---|---|---|---|---|
| (20) Расчетное значение температуры газов за (21) второй ступенью | $\vartheta''_р$ | $\vartheta''_I+(\vartheta''_{II}-\vartheta''_I)\times\frac{(Q_б-Q_т)_I}{(Q_б-Q_т)_I-(Q_б-Q_т)_{II}}$ | °C | $785+(805-785)\times\frac{604-561}{(604-561)-(560-574)}=800$ |
| (22) Теплосодержание газов за ступенью | $I''$ | (23) По $I\vartheta$-таблице | (7) ккал/кг | 1 637 |
| (24) Тепловосприятие ступени | $Q_б$ | $\left(I'-I''+\frac{\Delta\alpha_{пе}}{2}I^0_{х.в}\right)\varphi$ | " | $(2\,209-1\,637+1)\,0,995=571$. |
| (25) Теплосодержание пара на входе | $i'$ | $i_{п.п}-(Q_б+Q_л)\frac{B_p}{D}$ | " | $813,1-(571+29)\frac{41\,000}{230\,000}=706,1$ |
| (26) Температура пара на входе | $t'$ | (20) По приложению II | °C | 361 |

## (27) Расчет первой ступени

(28) Теплосодержание и температура газов на входе в ступень, а также теплосодержание и температура пара на выходе из нее определены при расчете второй ступени. Теплосодержание и температура газов за первой ступенью и соответственно величина дополнительного увлажнения пара в пароохладителе приняты при составлении баланса всего перегревателя в целом

| | | | | |
|---|---|---|---|---|
| (29) Тепло, передаваемое газами на участке испарения | $Q_{исп}$ | $\Delta i_{по}\cdot\frac{D}{B_p}$ | (7) ккал/кг | $15,1\,\frac{230\,000}{41\,000}=85$ |
| (30) Тепло, передаваемое газами на участке перегрева | $Q_{пе}$ | $(i''-i_{н.п})\frac{D}{B_p}$ | " | $(706,1-647,1)\frac{230\,000}{41\,000}=331$ |

Key: (1). Designation cf value. (2). Designation. (3). Calculation formula or method of determinaticn. (4). Dimensicnality. (5). Calculation. (6). Heat absorpticn cf step/stage cn balance. (7). kcal/kg. (8). Enthalpy cf steam at entrance intc second step/stage. (9). Temperature of steam at inlet. (10). On appendix. (11). Temperature head at entrance cf gases. (12). Temperature head at exit cf gases. (13). Average/mean temperature head with ccuntercurrent. (14). Parameter. (15). Ccafficient. (16). On ncmogram. (17). Temperature head in seccnd step/stage. (18). Heat absorption cf step/stage according tc equaticn of heat exchange. (19). Since this time of value $Q_{\text{п}}$ and $Q_{б}$ it is separated more than fcr 2c/c, ccmputed value $\theta_{\text{р}}''$ is determined by interpolaticn. (20). Ccmputed value of temperature of gases after seccrd step/stage. (22). Enthalpy of gases after step/stage. (23). On is-table. (24). Heat absorption of step/stage. (25). Enthalpy cf steam at entrance. (26). Temperature of steam at entrance. (27). Calculaticn of first stage. (28). Enthalpy and temperature cf gases at entrance intc step/stage, and also enthalpy and temperature of steam at output/yield from it are determined during calculaticn cf second step/stage. Heat content and temperature of gases after first stage and respectively the value of additional moistening cf steam in the steam cccler are accepted during the ccmpositicn cf the balance of entire superheater as a whole. (29). Heat, transmitted by gases in section of evaporation. (30). Heat, transmitted by gases in section cf superheating.

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Continued.

| (1) Наименование величины | (2) Обозначение | (3) Расчетная формула или способ определения | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| (6) Доля количества тепла, переданного на участке испарения, от полного тепловосприятия ступени | — | $\frac{Q_{исп}}{Q_{исп}+Q_{пе}}$ | — | $\frac{85}{85+331}=0,204$ |

(7) Так как эта доля больше 0,12 (см. п. 7-71), температурные напоры для испаряющей и перегревающей частей следует рассчитывать раздельно

| | | | | |
|---|---|---|---|---|
| (8) Теплосодержание газов за перегревающей частью (промежуточное)[1] | $I_{пр}$ | $I'-\frac{Q_{пе}}{\varphi}+\frac{\Delta\alpha_{пе}}{2}I^0_{х.в}$ | (9) ккал/кг | $1\,637-\frac{[illegible]}{0,995}+1=1\,304$ |
| (10) Температура газов за этой частью (при $\alpha''_{пе}=1,25$) | $\vartheta_{пр}$ | (11) По $I\vartheta$-таблице | °C | 639 |
| (12) Температурный напор на входе газов в перегревающую часть | $\Delta t'$ | $\vartheta'-t'$ | °C | $800-361=439$ |
| (13) То же на выходе из нее | $\Delta t_{пр}$ | $\vartheta_{пр}-t_{н.п}$ | °C | $639-317=322$ |
| (14) То же средний на участке перегрева | $\Delta t_{пе}$ | $\frac{\Delta t_{пр}+\Delta t'}{2}$ | °C | $\frac{322+439}{2}=380$ |
| (15) То же на выходе газов из ступени | $\Delta t''$ | $\vartheta''-t_{н.п}$ | °C | $601-317=284$ |
| (16) То же средний для участка испарения | $\Delta t_{исп}$ | $\frac{\Delta t_{пр}+\Delta t''}{2}$ | °C | $\frac{322+284}{2}=303$ |
| (17) Средний температурный напор ступени | $\Delta t_{ср}$ | $\frac{Q_{пе}+Q_{исп}}{\frac{Q_{пе}}{\Delta t_{пе}}+\frac{Q_{исп}}{\Delta t_{исп}}}$ | °C | $\frac{331+85}{\frac{331}{380}+\frac{85}{303}}=362$ |
| (18) Тепловосприятие ступени (по уравнению теплообмена) | $Q_т$ | $\frac{kH_1\Delta t_{ср}}{B_р}$ | (9) ккал/кг | $\frac{51,4\cdot797\cdot362}{41\,000}=362$ |
| (19) Отношение значений тепловосприятия | $\frac{Q_т}{Q_б}$ | $\frac{Q_т}{Q_{исп}+Q_{пе}}\cdot100$ | % | $\frac{362}{85+331}\cdot100=87$ |

(20) Так как значения $Q_т$ и $Q_б$ разнятся больше чем на 2%, необходимо произвести пересчет. (21) Для этого следует принять новое значение степени увлажнения в пароохладителе и пересчитать температурный напор в испаряющей части первой ступени; расчет перегревательной части не меняется

| | | | | |
|---|---|---|---|---|
| (22) Величина увлажнения пара в пароохладителе | $1-x$ | (23) Принимается повторно | — | 0,025 |
| (24) Тепловосприятие пароохладителя | $\Delta i_{по}$ | $r(1-x)$ | (9) ккал/кг | $302,9\cdot0,025=7,6$ |
| (25) Тепло, переданное в испарительной части | $Q_{исп}$ | $r(1-x)\frac{D}{B_р}$ | » | $7,6\frac{230\,000}{41\,000}=43$ |
| (26) Теплосодержание газов за перегревателем | $I''$ | $I_{пр}-\frac{Q_{исп}}{\varphi}$ | » | $1\,304-\frac{43}{0,995}=1\,261$ |
| (27) Температура газов за перегревателем | $\vartheta''$ | По $I\vartheta$-таблице | °C | 620 |
| (28) Температурный напор на выходе газов из ступени | $\Delta t''$ | $\vartheta''-t_{н.п}$ | °C | $620-317=303$ |

Key: (1). Designation of value. (2). Designation. (3). Calculation formula or method of determination. (4). Dimensionality. (5). Calculation. (6). Fraction/portion of quantity of heat, transmitted in section of evaporation, from full/total/complete heat absorption of step/stage. (7). Since this fraction/portion is more than 0.12 (see Section 7-71), temperature heads for vaporizing and superheating parts should be designed separately. (8). Enthalpy of gases after superheating part (intermediate) FOOTNOTE 1. For the simplification it is accepted that the suction of air occurs only in the superheating part of the step/stage. ENDFOOTNOTE.

(9). kcal/kg. (10). Temperature of gases after this part (when $\alpha''_{ne} = 1.25$ (11). On is-table. (12). Temperature head at entrance of gases into superheating part. (13). Then at output/yield from it. (14). Then average/mean in section of superheating. (15). Then at exit of gases from step/stage. (16). Then average/mean for section of evaporation. (17). Average/mean temperature head of step/stage. (18). Heat absorption of step/stage (according to equation of heat exchange. (19). Relation of values of heat absorption. (20). Since value $Q_m$ and $Q_6$ it is separated more than for 2c/o, it is necessary to manufacture recalculation. (21). For this should be taken new value of degree of moistening in steam cooler and counted over temperature head in vaporizing part of first stage; calculation of

superheater part is not changed. (22). Value of moistening steam in steam cooler. (23). It is accepted repeatedly. (24). Heat absorption of steam cooler. (25). Heat, transmitted in evaporative part. (26). Enthalpy of gases after superheater. (27). Temperature of gases after superheater. (28). Temperature head at exit of gases from step/stage.

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Continued.

| (1) Наименование величины | (3) Обозначение | (2) Расчетная формула или способ определения | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| (6) Средний температурный напор для участка испарения | $\Delta t_{исп}$ | $\frac{\Delta t_{пр}+\Delta t''}{2}$ | °C | $\frac{322+303}{2}=312$ |
| (7) Средний температурный напор ступени | $\Delta t_{ср}$ | $\frac{Q_{пе}+Q_{исп}}{\frac{Q_{пе}}{\Delta t_{пе}}+\frac{Q_{исп}}{\Delta t_{исп}}}$ | °C | $\frac{331+43}{\frac{331}{380}+\frac{43}{312}}=371$ |
| (8) Тепловосприятие ступени[1] | $Q_m$ | $\frac{kH_1\,\Delta t_{ср}}{B_р}$ | (9) ккал/кг | $\frac{51{,}4\cdot 797\cdot 371}{41\,000}=371$ |
| (10) Отношение значений тепловосприятия | $\frac{Q_m}{Q_б}$ | $\frac{Q_m}{Q_{пе}+Q_{исп}}\,100$ | % | $\frac{371}{331+43}\cdot 100=99$ |

(11) Так как значения $Q_m$ и $Q_б$ разнятся меньше чем на 2%, расчет перегревателя считается законченным

| | | | | |
|---|---|---|---|---|
| (12) Расчетное тепловосприятие первой ступени | $Q_б$ | $Q_{пе}+Q_{исп}$ | (9) ккал/кг | $331+43=374$ |

(13) **Расчет второй ступени экономайзера**

| | | | | |
|---|---|---|---|---|
| (14) Диаметр труб | $d$ | (15) По конструктивным характеристикам | мм | 38×4,5 |
| (16) Живое сечение для прохода газов | $F$ | То же (17) | м² | 19,8 |
| (18) Относительный поперечный шаг труб | $s_1/d$ | » » | — | 2,77 |
| (19) Относительный продольный шаг труб | $s_2/d$ | » » | — | 1,97 |
| (20) Эффективная толщина газового слоя | $s'$ | » » | м | 0,236 |
| (21) Число рядов труб | $z_2$ | » » | — | 28 |
| (22) Поверхность нагрева | $H$ | (24) » » | м² | 952 |
| (23) Температура газов на входе | $\vartheta'$ | Из расчета перегревателя | °C | 620 |
| (25) Теплосодержание газов на входе | $I'$ | То же (17) | (9) ккал/кг | 1 261 |
| (26) Теплосодержание воды на выходе из экономайзера (ориентировочно)[2] | $i''$ | $i_{н.п}-\frac{B_р}{D}(Q_с+Q_к+$ (28) $+Q_{пе})+\Delta i_{по}$ | » | $813{,}1-\frac{41\,000}{230\,000}(1\,780+$ $+116+571+371)+7{,}6=$ $=314{,}0$ |
| (27) Температура воды на выходе из экономайзера | $t''$ | По приложению II при (30) давлении $p_б$ | °C | 295 |
| (29) Температура газов на выходе из второй ступени | $\vartheta''$ | Принимается с последующим уточнением | °C | 440 |
| (31) Теплосодержание газов на выходе из ступени | $I''$ | (32) По $I\vartheta$-таблице | (9) ккал/кг | 886 |
| (33) Тепловосприятие ступени по балансу | $Q_б$ | $(I'-I''+\Delta\alpha\, I^0_{х.в})\,\varphi$ | » | $(1\,261-886+1)\,0{,}995=374$ |
| (34) Теплосодержание воды на входе во вторую ступень | $i'$ | $i''-Q_б\frac{B_р}{D}$ | » | $314{,}0-374\frac{41\,000}{230\,000}=247{,}4$ |

Key: (1). Designation of value. (2). Designation. (3). Calculation formula or method of determination. (4). Dimensionality. (5). Calculation. (6). Average/mean temperature head for section of evaporation. (7). Average/mean temperature head of step/stage. (8). Heat absorption of step/stage [1].

FOOTNOTE [1]. Since the temperature of gases differs from that previously accepted less than by 50°C, the coefficient of heat transfer for the superheater is not counted over. ENDFOOTNOTE.

(9). kcal/kg. (10). Relation of values of heat absorption. (11). Since value $Q_m$ and $Q_6$ it is separated less than for 2c/o, calculation of superheater is considered completed. (12). Calculated heat absorption of first stage. (13). Calculation of second step/stage of economizer. (14). Diameter of ducts. (15). According to structural/design characteristics. (16). Clear opening for pass of gases. (17). Then. (18). Relative transverse pitch of ducts. (19). Relative longitudinal pitch of ducts. (20). Efficient thickness of gas layer. (21). Number of runs of pipes. (22). Heating surface. (23). Temperature of gases at entrance. (24). From calculation of superheater. (25). Enthalpy of gases at entrance. (26). Enthalpy of water at output/yield from economizer (tentatively) [2].

FOOTNOTE 2. $Q_л, Q_к$ and $Q_{пе}$ - heat sensing on the balance in the heating, the scallop and the superheater; $\Delta i_{по}$ - heat sensing of steam cooler. ENDFOOTNOTE. (27). Temperature in at output/yield from economizer. (28). On appendix II at pressure $p_б$. (29). Temperature of gases at output/yield from second step/stage. (30). It is accepted with subsequent refinement. (31). Enthalpy of gases at output/yield from step/stage. (32). On i8-table. (33). Heat absorption of step/stage on balance. (34). Enthalpy of water at entrance into second step/stage.

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Continued.

| (1) Наименование величины | (2) Обозначение | (3) Расчетная формула или способ определения | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| (6) Температура воды на входе в ступень | $t'$ | (7) По приложению II | °C | 239 |
| (8) Температурный напор на входе газов | $\Delta t'$ | $\vartheta' - t''$ | °C | 620—295=325 |
| (9) То же на выходе | $\Delta t''$ | $\vartheta'' - t'$ | °C | 440—239=201 |
| (10) Средний температурный напор | $\Delta t_{npm}$ | $\frac{(\Delta t' + \Delta t'')}{2}$ | °C | $\frac{325+201}{2} = 263$ |
| (11) Средняя температура газов | $\vartheta$ | $\frac{\vartheta' + \vartheta''}{2}$ | °C | $\frac{620+440}{2} = 530$ |
| (12) Средняя температура воды | $t$ | $\frac{t' + t''}{2}$ | °C | $\frac{239+295}{2} = 267$ |
| (13) Температура загрязненной стенки | $t_з$ | $t+100$ | °C | 267+100=367 |
| (14) Объем газов на 1 *кг* топлива при $\alpha = 1,26$ | $V_г$ | (15) По табл. 1 | (15a) *нм³/кг* | 5,62 |
| (16) Объемная доля водяных паров | $r_{H_2O}$ | (17) То же | — | 0,090 |
| (18) Объемная доля трехатомных газов | $r_n$ | » » | — | 0,224 |
| (19) Концентрация золы в дымовых газах | $\mu$ | » » | (19a) *г/нм³* | 64,0 |
| (20) Средняя скорость газов | $w$ | $\frac{B_p V_г}{3600\ F} \cdot \frac{\vartheta + 273}{273}$ | (20a) *м/сек* | $\frac{41\,000 \cdot 5,62\,(530+273)}{3600 \cdot 19,8 \cdot 273} = 9,5$ |
| (21) Коэффициент теплоотдачи конвекцией | $\alpha_к$ | (22) По номограмме III | (21a) $\frac{ккал}{м^2\ час\ град}$ | 74,0 |
| (23) Суммарная поглощательная способность трехатомных газов | $p_n s$ | $r_n s'$ | *м ата* (23a) | 0,224·0,236=0,053 |
| (24) Коэффициент ослабления лучей трехатомными газами | $k_г$ | (22) По номограмме IX | — | 2,9 |
| (25) Коэффициент ослабления лучей золовыми частицами | $k_n$ | (22) По номограмме X | — | 0,0147 |
| (26) Сила поглощения запыленного потока | $ks$ | $(k_г r_n + k_n \mu)\, s$ | — | (2,9·0,224+0,0147·64)× ×0,236=0,376 |
| (27) Коэффициент теплоотдачи излучением | $\alpha_л$ | (22) По номограмме XI | (21a) $\frac{ккал}{м^2\ час\ град}$ | 21,1 |
| (28) Коэффициент загрязнения | $\varepsilon$ | (22) По номограмме XII | $\frac{м^2\ час\ град}{ккал}$ (29) | 0,0036·1,0·1,0+0,002= =0,0056 |
| (30) Коэффициент теплопередачи | $k$ | $\frac{\alpha_к + \alpha_л}{1 + \varepsilon\,(\alpha_к + \alpha_л)}$ | (21a) $\frac{ккал}{м^2\ час\ град}$ | $\frac{74,0+21,1}{1+0,0056\,(74,0+21,1)} = 62,0$ |
| (31) Тепловосприятие экономайзера по уравнению теплопередачи | $Q_m$ | $\frac{kH\Delta t}{B_p}$ | (32) *ккал/кг* | $\frac{62,0 \cdot 952 \cdot 263}{41\,000} = 378$ |

(33) Поскольку расхождение между $Q_б$ и $Q_m$ меньше 2%, расчет на этом заканчивается.

(34) Расчет второй ступени воздухоподогревателя

| | | | | |
|---|---|---|---|---|
| (35) Диаметр труб | $d$ | (36) По конструктивным характеристикам | *мм* | 51×1,5 |
| (37) Относительный поперечный шаг труб | $s_1/d$ | (17) То же | — | 1,57 |

Key: (1). Designation of value. (2). Designation. (3). Calculation formula or method of determination. (4). Dimensionality. (5). Calculation. (6). Temperature of water at stage inlet. (7). On appendix. (8). Temperature head at entrance of gases. (9). Then at output/yield. (10). Average/mean temperature head. (11). Mean temperature of gases. (12). Mean temperature of water. (13). Temperature of contaminated wall. (14). Volume of gases on 1 kg of fuel/propellant with $\alpha$=1.26. (15). On Tables 1. (15a). $nm^3$/kg. (16). Volume fraction of water vapors. (17). Then. (18). Volume fraction of triatomic gases. (19). Ash concentration in flue gases. (19a). g/$nm^3$. (20). Average/mean gas velocity. (21). Convection heat-transfer coefficient. (21a). kcal/$m^2$ hour deg. (22). On nomogram. (23). Total absorptivity of triatomic gases. (24). Coefficient of attenuation of rays/beams by triatomic gases. (25). Coefficient of weakening rays/beams by ash particles. (26). Absorption strength of dusty flow. (27). Radiation heat-transfer coefficient. (28). Contamination factor. (29). $m^2$ hour deg/kcal. (30). Coefficient of heat transfer. (31). Heat absorption of economizer according to equation of heat transfer. (32). kcal/kg. (33). Since disagreement between $Q_б$ and $Q_т$ less than 2o/o, calculation on this is finished. (34). Calculation of secondary air heater. (35). Diameter of ducts. (36). According to structural/design characteristics. (37). Relative transverse pitch of ducts.

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Continued.

| (1) Наименование величины | (2) Обозначение | (3) Расчетная формула или способ определения | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| (6) Относительный продольный шаг труб | $s_2/d$ | (7) По конструктивным характеристикам | — | 1,08 |
| (8) Число рядов труб | $z_2$ | (9) То же | — | 55 |
| (10) Число ходов по воздуху | $n$ | » » | — | 2 |
| (11) Живое сечение для прохода газов | $F$ | » » | $м^2$ | 11,3 |
| (12) Живое сечение для прохода воздуха | $f$ | » » | $м^2$ | 10,1 |
| (13) Поверхность нагрева | $H$ | (15) » » | $м^2$ | 5 420 |
| (14) Температура газов на входе | $\vartheta'$ | Из расчета второй ступени экономайзера | °C | 440 |
| (16) Теплосодержание газов на входе | $I'$ | (9) То же | (16a) ккал/кг | 886 |
| (17) Температура воздуха на выходе | $t'' = t_{г.в}$ | (18) Подставляется температура воздуха, принятая в расчете топки | °C | 345 |
| (19) Теплосодержание теоретически необходимого количества воздуха при $t''$ | $I_в^{0''}$ | (20) По $I\vartheta$-таблице | (16a) ккал/кг | 461 |
| (21) Отношение количества воздуха на выходе к теоретически необходимому[1] | $\beta''_{вп}$ | (22) Из расчета топки | — | 1,03 |
| (23) Присос воздуха во второй ступени | $\Delta\alpha_{вп II}$ | (24) По табл. 1 | — | 0,05 |
| (25) Температура воздуха на входе во вторую ступень | $t$ | (26) Принимается с последующим уточнением | °C | 160 |
| (27) Теплосодержание теоретически необходимого количества воздуха на входе | $I_в^{0'}$ | (20) По $I\vartheta$-таблице | (16a) ккал/кг | 211 |
| (28) Тепловосприятие воздуха по балансу | $Q_б$ | $\left(\beta''_{вп} + \frac{\Delta\alpha_{вп II}}{2}\right)\left(I_в^{0''} - I_в^{0'}\right)$ | (16a) ккал/кг | $\left(1{,}03 + \frac{0{,}05}{2}\right)(461 - 211) = 264$ |
| (29) Средняя температура воздуха | $t$ | $\frac{t' + t''}{2}$ | °C | $\frac{160 + 345}{2} = 252$ |
| (30) Теплосодержание теоретически необходимого количества воздуха при средней температуре | $I_{прс}$ | (20) По $I\vartheta$-таблице | (16a) ккал/кг | 334 |
| (31) Теплосодержание газов на выходе из воздухоподогревателя | $I''$ | $I' - \frac{Q_б}{\varphi} + \Delta\alpha_{вп II} I_{прс}$ | (16a) ккал/кг | $886 - \frac{264}{0{,}995} + 17 = 637$ |
| (32) Температура газов на выходе | $\vartheta''$ | (20) По $I\vartheta$-таблице | °C | 311 |
| (33) Средняя температура газов | $\vartheta$ | $\frac{\vartheta' + \vartheta''}{2}$ | °C | $\frac{440 + 311}{2} = 375$ |
| (34) Объем газов на 1 кг топлива при $\alpha_{ср}$ | $V_г$ | (24) По табл. 1 | (35) $нм^3/кг$ | 5,76 |

Key: (1). Designation of value. (2). Designation. (3). Calculation formula or method of determination. (4). Dimensionality. (5). Calculation. (6). Relative longitudinal pitch of ducts. (7). According to structural/design characteristics. (8). Number of runs of pipes. (9). Then. (10). Number of courses by air. (11). Clear opening for pass of gases. (12). Clear opening for pass of air. (13). Heating surface. (14). Temperature of gases at entrance. (15). From calculation of second step/stage of economizer. (16). Enthalpy of gases at entrance. (16a). kcal/kg. (17). Temperature of air at output/yield. (18). Is substituted temperature of air, accepted in calculation of heating. (19). Enthalpy of theoretically necessary quantity of air with t''. (20). On iϑ-table. (21). Ratio of quantity of air at output/yield to theoretically necessary [1].

FOOTNOTE [1]. In view of the small given humidity of fuel/propellant the recirculation of air is not provided for. ENDFOOTNOTE.

(22). From calculation of heating. (23). Suction of air in second step/stage. (24). On Tables 1. (25). Temperature of air at the inlet into second step/stage. (26). It is accepted with subsequent refinement. (27). Enthalpy of theoretically necessary quantity of air at entrance. (28). Heat absorption of air or balance. (29). Mean temperature of air. (30). Enthalpy of theoretically necessary

quantity of air at mean temperature. (31). Enthalpy of gases at output/yield from air preheater. (32). Temperature of gases at output/yield. (33). Mean temperature of gases. (34). Volume of gases on 1 kg of fuel/propellant when $\alpha_{cp}$

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Continued.

| (1) Наименование величины | (2) Обозначение | (3) Расчетная формула или способ определения | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| (6) Объемная доля водяных паров | $r_{H_2O}$ | (7) По табл. 1 | — | 0,088 |
| (8) Средняя скорость газов | $w$ | $\frac{B_p V_г}{3\,600\ F} \frac{\vartheta+273}{273}$ | (9) м/сек | $\frac{41\,000 \cdot 5,76\,(375+273)}{3\,600 \cdot 11,3 \cdot 273} = 13,8$ |
| (10) Коэффициент теплоотдачи с газовой стороны | $\alpha_1$ | (11) По номограмме IV | (12) $\frac{ккал}{м^2\ час\ град}$ | 36,1 |
| (13) Теоретически необходимый объем воздуха | $V^0$ | (7) По табл. 1 | $нм^3/кг$ | 4,15 |
| (14) Средняя скорость воздуха | $w_в$ | $\frac{\left(\beta''_{вп}+\frac{\Delta\alpha}{2}\right) B_p V^0(t+273)}{3\,600 \cdot 273\, f}$ | (9) м/сек | $\left(1,03+\frac{0,06}{2}\right) \times \frac{41\,000 \cdot 4,15\,(252+273)}{3\,600 \cdot 273 \cdot 10,1} = 9,8$ |
| (15) Коэффициент теплоотдачи с воздушной стороны | $\alpha_2$ | (11) По номограмме III | (12) $\frac{ккал}{м^2\ час\ град}$ | 66,0 |
| (16) Коэффициент использования поверхности нагрева | $\varepsilon$ | (17) По табл. номограммы XII | — | 0,75 |
| (18) Коэффициент теплопередачи | $k$ | $\varepsilon \frac{\alpha_1 \alpha_2}{\alpha_1+\alpha_2}$ | (12) $\frac{ккал}{м^2\ час\ град}$ | $0,75\ \frac{36,1 \cdot 66,0}{102,1} = 17,5$ |
| (19) Температурный напор на входе газов | $\Delta t'$ | $\vartheta' - t''$ | °C | 440—345=95 |
| (20) Температурный напор на выходе | $\Delta t''$ | $\vartheta'' - t'$ | °C | 311—160=151 |
| (21) Температурный напор при противотоке | $\Delta t_{прт}$ | $\frac{\Delta t' + \Delta t''}{2}$ | °C | $\frac{95+151}{2} = 123$ |
| (22) Больший перепад температур | $\tau_б$ | $t'' - t'$ | °C | 345—160=185 |
| (23) Меньший перепад температур | $\tau_м$ | $\vartheta' - \vartheta''$ | °C | 440—311=129 |
| (24) Параметр | $P$ | $\frac{\tau_м}{\vartheta' - t'}$ | — | $\frac{129}{440-160} = 0,462$ |
| (24) Параметр | $R$ | $\frac{\tau_б}{\tau_м}$ | — | $\frac{185}{129} = 1,43$ |
| (25) Коэффициент | $\psi$ | (11) По номограмме XV | — | 0,93 |
| (26) Температурный напор | $\Delta t$ | $\psi \Delta t_{прт}$ | °C | 0,93·123=114 |
| (27) Тепловосприятие воздухоподогревателя по уравнению теплопередачи | $Q_m$ | $\frac{kH\Delta t}{B_p}$ | (28) ккал/кг | $\frac{17,5 \cdot 5\,420 \cdot 114}{41\,000} = 264$ |
| | | (29) $Q$ и $Q_m$ совпадают | | |

Key: (1). Designation of value. (2). Designation. (3). Calculation formula or method of determination. (4). Dimensionality. (5). Calculation. (6). Volume fraction of water vapors. (7). On Tables 1. (8). Average/mean gas velocity. (9). m/s. (10). Heat-transfer coefficient from gas side. (11). On nomogram. (12). kcal/m²h deg. (13). Theoretically necessary volume of air. (14). Average/mean air speed. (15). Heat-transfer coefficient from air side. (16). Coefficient of use of heating surface. (17). On tables of nomogram. (18). Coefficient of heat transfer. (19). Temperature pressure head at entrance of gases. (20). Temperature head at output/yield. (21). Temperature head with countercurrent. (22). Larger temperature differential. (23). Smaller temperature differential. (24). Parameter. (25). Coefficient. (26). Temperature head. (27). Heat absorption of air preheater according to equation of heat transfer. (28). kcal/kg. (29). Q and Qm coincide.

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Continued.

| (1) Наименование величины | (2) Обозначение | (3) Расчетная формула или способ определения | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| **(6) Расчет первой ступени экономайзера (по ходу воды)** | | | | |
| (7) Диаметр труб | $d$ | (8) По конструктивным характеристикам | мм | 38×4,5 |
| (9) Живое сечение для прохода газов | $F$ | (10) То же | м² | 18,0 |
| (11) Относительный поперечный шаг | $s_1/d$ | » | — | 2,77 |
| (12) Относительный продольный шаг | $s_2/d$ | » | — | 1,97 |
| (13) Число рядов труб | $z_2$ | » | — | 56 |
| (14) Поверхность нагрева | $H$ | (15) » | м² | 1 720 |
| (16) Температура газов на входе | $\vartheta'$ | Из расчета воздухоподогревателя второй ступени | °C | 311 |
| (17) Теплосодержание газов на входе | $I'$ | (18) То же | (17a) ккал/кг | 637 |
| (18) Теплосодержание воды на входе в экономайзер[1] | $i'$ | $i_{п.в}+\Delta i_{по}$ | » | 220,6+7,6=228,2 |
| (19) Температура воды на входе в экономайзер | $t'$ | (19a) По приложению II (21) при $p_б$ | °C | 222 |
| (20) Температура газов на выходе из экономайзера | $\vartheta''$ | Принимается с последующим уточнением | °C | 270 |
| (22) Теплосодержание газов на выходе | $I''$ | (23) По $I\vartheta$-таблице | (17a) ккал/кг | 557 |
| (24) Тепловосприятие экономайзера по балансу | $Q_б$ | $(I'-I''+\Delta\alpha I^0_{х.в})\varphi$ | » | (637−557+1) 0,995=81 |
| (25) Теплосодержание воды на выходе из первой ступени | $i''$ | $i'+Q_б\dfrac{B_р}{D_{эк}}$ | » | $228,2+81\dfrac{41\,000}{230\,000}=242,6$ |
| (26) Температура воды на выходе из первой ступени | $t''$ | (27) При $p_б$ | °C | 235 |
| (28) Температурный напор на входе газов | $\Delta t'$ | $\vartheta'-t''$ | °C | 311−235=76 |
| (29) Температурный напор на выходе | $\Delta t''$ | $\vartheta''-t'$ | °C | 270−222=48 |
| (30) Средний температурный напор | $\Delta t$ | $\dfrac{\Delta t'+\Delta t''}{2}$ | °C | $\dfrac{76+48}{2}=62$ |
| (31) Средняя температура газов | $\vartheta$ | $\dfrac{\vartheta'+\vartheta''}{2}$ | °C | $\dfrac{311+270}{2}=290$ |
| (32) Средняя температура воды | $t$ | $\dfrac{t'+t''}{2}$ | °C | $\dfrac{222+235}{2}=228$ |
| (33) Температура загрязненной стенки | $t_з$ | $t+25$ | °C | 228+25=253 |
| (34) Объем газов на 1 кг топлива | $V_г$ | (34a) По табл. 1 | (34b) нм³/кг | 5,91 |
| (35) Объемная доля водяных паров | $r_{H_2O}$ | (10) То же | — | 0,087 |
| (36) Объемная доля трехатомных газов | $r_п$ | » | — | 0,214 |
| (37) Концентрация золы в дымовых газах | $\mu$ | » | (38) г/нм³ | 61,0 |

Key: (1). Designation of value. (2). Designation. (3). Calculation formula or method of determination. (4). Dimensionality. (5). Calculation. (6). Calculation of first stage of economizer (on course of water). (7). Diameter of ducts. (8). According to structural/design characteristics. (9). Clear opening for pass of gases. (10). Then. (11). Relative transverse pitch. (12). Relative longitudinal pitch. (13). Number of runs of pipes. (14). Heating surface. (15). From calculation of air preheater of second step/stage. (16). Temperature of gases at entrance. (17). Enthalpy of gases at entrance. (17a). kcal/kg. (18). Enthalpy of water at entrance into economizer [1].

FOOTNOTE [1]. The heat absorption of steam cooler $u_{no}$ is taken according to the calculation of superheater. ENDFOOTNOTE.

(19). Temperature of water at entrance into economizer. (19a). On appendix. (20). Temperature of gases at output/yield from economizer. (21). It is accepted with subsequent refinement. (22). Enthalpy of gases at output/yield. (23). On is-table. (24). Heat sensing of economizer on balance. (25). Enthalpy of water at output/yield from first stage. (26). Temperature of water at output/yield from first stage. (27). With. (28). Temperature head at entrance of gases. (29). Temperature head at output/yield. (30). Average/mean temperature

head. (31). Mean temperature of gases. (32). Mean temperature of water. (33). Temperature of contaminated wall. (34). Volume of gases on 1 kg of fuel/propellant. (34a). On Tables 1. (34b). $nm^3$/kg. (35). Volume fraction of water vapors. (36). Volume fraction of triatomic gases. (37). Ash concentration in flue gases. (38). $g/nm^3$.

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Continued.

| (1) Наименование величины | (2) Обозначение | (3) Расчетная формула или способ определения | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| (6) Средняя скорость газов | $w$ | $\frac{B_p V_г}{3600\ F} \cdot \frac{\vartheta+273}{273}$ | (7) $м/сек$ | $\frac{41\,000 \cdot 5{,}91\,(290+273)}{3600 \cdot 18{,}0 \cdot 273}=7{,}7$ |
| (8) Коэффициент теплоотдачи конвекцией | $\alpha_к$ | (9) По номограмме III | (10) $\frac{ккал}{м^2\ час\ град}$ | 65,0 |
| (11) Суммарная поглощательная способность трехатомных газов | $p_n s$ | $r_n s$ | (12) $м\ ата$ | $0{,}213 \cdot 0{,}181=0{,}0386$ |
| (13) Коэффициент ослабления лучей трехатомными газами | $k_г$ | (9) По номограмме IX | — | 3,7 |
| (14) Коэффициент ослабления лучей золовыми частицами | $k_n$ | (9) По номограмме X | — | 0,0185 |
| (15) Сила поглощения запыленного потока | $ks$ | $(k_г \cdot r_n+k_n\mu)\,s$ | — | $(3{,}7 \cdot 0{,}214+0{,}0185 \cdot 61) \times \times 0{,}181=0{,}36$ |
| (16) Коэффициент теплоотдачи излучением | $\alpha_л$ | (9) По номограмме XI | (10) $\frac{ккал}{м^2\ час\ град}$ | 8,4 |
| (18) Коэффициент загрязнения | $\varepsilon$ | (9) По номограмме XII | (19) $\frac{м^2\ час\ град}{ккал}$ | 0,0045 |
| (20) Коэффициент теплопередачи | $k$ | $\frac{\alpha_к+\alpha_л}{1+\varepsilon\,(\alpha_к+\alpha_л)}$ | (10) $\frac{ккал}{м^2\ час\ град}$ | $\frac{65{,}0+8{,}4}{1+0{,}0045\,(65{,}0+8{,}4)}= =55{,}2$ |
| (21) Тепловосприятие ступени по уравнению теплопередачи | $Q_т$ | $\frac{kH\Delta t}{B_p}$ | (17) $ккал/кг$ | $\frac{55{,}2 \cdot 1\,720 \cdot 62}{41\,000}=144$ |

(22) Поскольку $Q_т$ и $Q_б$ заметно различаются, вновь задаемся значением $\vartheta''$

| | | | | |
|---|---|---|---|---|
| (23) Температура газов на выходе | $\vartheta''$ | (24) Принимается с последующим уточнением | °C | 250 |
| (25) Теплосодержание газов на выходе | $I''$ | (26) По $I\vartheta$-таблице | (17) $ккал/кг$ | 514 |
| (27) Тепловосприятие экономайзера по балансу | $Q_б$ | $(I'-I''+\Delta\alpha I^0_{х.в})\,\varphi$ | » | $(637-514+1)\,0{,}995=123$ |
| (28) Теплосодержание воды на выходе | $i''$ | $i'+Q_б \frac{B_p}{D_{эк}}$ | » | $228{,}2+123\,\frac{41\,000}{230\,000}=250{,}1$ |
| (29) Температура воды на выходе | $t''$ | (30) По приложению II | °C | 242 |
| (31) Температурный напор на входе газов | $\Delta t'$ | $\vartheta'-t''$ | °C | $311-242=69$ |
| (32) Температурный напор на выходе | $\Delta t''$ | $\vartheta''-t'$ | °C | $250-222=28$ |
| (33) Средний температурный напор | $\Delta t$ | $\frac{\Delta t'-\Delta t''}{2{,}3\lg\frac{\Delta t'}{\Delta t''}}$ | °C | $\frac{69-28}{2{,}3\lg\frac{69}{28}}=45$ |
| (34) Тепловосприятие ступени по уравнению теплообмена | $Q_т$ | $\frac{kH\Delta t}{B_p}$ | (17) $ккал/кг$ | $\frac{55{,}2 \cdot 1\,720 \cdot 45}{41\,000}=104$ |
| (35) Отношение значений тепловосприятия | — | $\frac{Q_т}{Q_б} \cdot 100$ | % | $\frac{104}{123} \cdot 100=85$ |

(36) Расхождение между $Q_б$ и $Q_т$ также больше 2%. Поэтому расчетная температура газов за ступенью определяется при помощи графической интерполяции (фиг. 16)

Key: (1). Designation cf value. (2). Designation. (3). Calculation formula or method of determination. (4). Dimensionality. (5). Calculation. (6). Average/mean gas velocity. (7). m/s. (8). Convection heat-transfer coefficient. (9). On nomogram. (10). kcal/m² hour deg. (11). Total absorptivity of triatomic gases. (12). m atm(abs.). (13). Coefficient of weakening rays/beams by triatomic gases. (14). Coefficient of weakening rays/beams by ash particles. (15). Absorption strength of dusty flow. (16). Radiation heat-transfer coefficient. (17). kcal/kg. (18). Contamination factor. (19). m² hour deg/kcal. (20). Coefficient of heat transfer. (21). Heat absorption of step/stage according to equation of heat transfer. (22). Since $Q_m$ and $Q_6$ noticeably are distinguished, we are again assigned by value ϑ''. (23). Temperature of gases at output/yield. (24). It is accepted with subsequent refinement. (25). Enthalpy of gases at output/yield. (26). On iϑ-table. (27). Heat sensing of economizer on balance. (28). Enthalpy of water at output/yield. (29). Temperature of water at output/yield. (30). On appendix. (31). Temperature pressure head at entrance of gases. (32). Temperature head at output/yield. (33). Average/mean temperature head. (34). Heat absorption of step/stage according to equation of heat exchange. (35). Relation of values of heat absorption. (36). Disagreement between $Q_6$ and $Q_m$ is also more than 2o/o. Therefore the calculated temperature of gases after the step/stage is determined with the help of graphic interpolation (Fig. 16).

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Continued.

| (1) Наименование величины | Обозначение (2) | Расчетная формула или способ определения (3) | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| (6) Температура газов на выходе из первой ступени | $\vartheta''$ | (7) По фиг. 16 | °C | 255 |
| (8) Теплосодержание газов на выходе из ступени | $I''$ | (9) По $I\vartheta$-таблице | (9a) ккал/кг | 525 |
| (10) Тепловосприятие ступени | $Q_б$ | $(I'-I''+\Delta\alpha I^0_{х.в})\varphi$ | • | $(637-525+1)\,0{,}995=112$ |
| (11) Теплосодержание воды на выходе | $i''$ | (13) $i'+Q_б\dfrac{B_р}{D_{эк}}$ | • | $228{,}2+112\dfrac{41\,000}{230\,000}=248{,}2$ |
| (12) Температура воды на выходе | $t''$ | По приложению II | °C | 240 |
| **(14) Расчет первой ступени воздухоподогревателя** | | | | |
| (15) Диаметр труб | $d$ | (16) По конструктивным характеристикам | мм | 51×1,5 |
| (17) Поперечный относительный шаг труб | $s_1/d$ | То же (18) | — | 1,57 |
| (19) Продольный относительный шаг труб | $s_2/d$ | » » | — | 1,08 |
| (20) Число рядов труб | $z_2$ | » » | — | 55 |
| (21) Число ходов по воздуху | $n$ | » » | — | 2 |
| (22) Живое сечение для прохода газов | $F$ | » » | м² | 11,3 |
| (23) Живое сечение для прохода воздуха | $f$ | » » | м² | 10,1 |
| (24) Поверхность нагрева | $H$ | (26) » » | м² | 5 420 |
| (25) Температура газов на входе | $\vartheta'$ | Из расчета экономайзера первой ступени | °C | 255 |
| (27) Теплосодержание газов на входе | $I'$ | То же (18) | (9a) ккал/кг | 525 |
| (28) Температура воздуха на входе | $t'$ | (29) Принята | °C | 30 |
| (30) Теплосодержание теоретически необходимого количества воздуха при $t'$ 10° | $I^{0'}_в$ | (9) По $I\vartheta$-таблице | (9a) ккал/кг | 39,2 |

Key: (1). Designation of value. (2). Designation. (3). Calculation formula or method of determination. (4). Dimensionality. (5). Calculation.

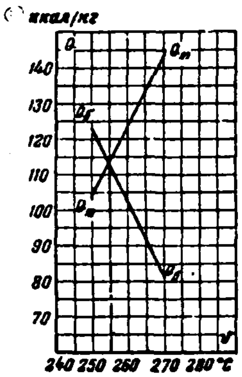


Fig. 16. Graphic determination of temperature of gases after first stage of economizer.

Key: (1). kcal/kg.

(6). Temperature of gases at output/yield from first stage. (7). On Fig. 16. (8). Enthalpy of gases at output/yield from step/stage. (9). On iϑ-table. (9a). kcal/kg. (10). Heat absorption of step/stage. (11). Enthalpy of water at output/yield. (12). Temperature of water at output/yield. (13). On appendix. (14). Calculation of first stage of air preheater. (15). Diameter of ducts. (16). According to structural/design characteristics. (17). Transverse relative spacing between tubes. (18). Then. (19). Longitudinal relative spacing between tubes. (20). Number of runs of pipes. (21). Number of courses

by air. (22). Clear opening for pass of gases. (23). Clear opening for pass of air. (24). Heating surface. (25). Temperature of gases at entrance. (26). Of calculation of economizer of first stage. (27). Enthalpy of gases at entrance. (28). Temperature of air at the inlet. (29). It is accepted. (30). Enthalpy of theoretically necessary quantity of air with t'.

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Continued.

| (1) Наименование величины | (2) Обозначение | (3) Расчетная формула или способ определения | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| (6) Температура воздуха на выходе | $t''$ | (7) Принимается с последующим уточнением | °C | 173 |
| (8) Теплосодержание теоретически необходимого количества воздуха при $t''$ | $I_в^{0''}$ | (9) По It-таблице | (10) ккал/кг | 228 |
| (10) Отношение количества воздуха на выходе из первой ступени к теоретически необходимому | $\beta''_{вп1}$ | $\beta''_{вп} + \Delta\alpha_{вп1}$ | — | $1,03+0,05=1,08$ |
| (11) Тепловосприятие воздуха по балансу | $Q_в$ | $\left(\beta_{вп1} + \frac{\Delta\alpha_{вп1}}{2}\right)(I_в^{0''} - I_в^{0'})$ | (9) ккал/кг | $\left(1,08+\frac{0,05}{2}\right)(228-39,2)=209$ |
| (12) Средняя температура воздуха | $t$ | $\frac{t'+t''}{2}$ | °C | $\frac{173+30}{2}=101$ |
| (13) Теплосодержание теоретически необходимого количества воздуха при средней температуре | $I^0_{прс}$ | (9) По It-таблице | ккал/кг | 132 |
| (14) Теплосодержание газов на выходе из воздухоподогревателя | $I''$ | $I' - \frac{Q_в}{\varphi} + \Delta\alpha I^0_{прс}$ | " | $525 - \frac{209}{0,995} + 7=322$ |
| (15) Температура газов на выходе | $\vartheta''$ | (9) По It-таблице | °C | 154 |
| (16) Средняя температура газов | $\vartheta$ | $\frac{\vartheta'+\vartheta''}{2}$ | °C | $\frac{255+154}{2}=204$ |
| (17) Объем газов на 1 кг топлива | $V_г$ | (18) По табл. 1 | (19) нм³/кг | 6,06 |
| (20) Объемная доля водяных паров | $r_{H_2O}$ | " | — | 0,085 |
| (21) Средняя скорость газов | $w_г$ | $\frac{B_р V_г}{3600 F}\cdot\frac{\vartheta+273}{273}$ | (22) м/сек | $\frac{6,06\cdot41\,000(204+273)}{3600\cdot11,3\cdot273}=10,7$ |
| (23) Коэффициент теплоотдачи с газовой стороны | $\alpha_1$ | (24) По номограмме IV | (25) $\frac{ккал}{м^2\,час\,град}$ | 33,2 |
| (26) Средняя скорость воздуха | $w_в$ | $\frac{\left(\beta_{вп1}+\frac{\Delta\alpha_{вп1}}{2}\right)B_р V^0(t+273)}{3600\cdot f\cdot273}$ | (22) м/сек | $\left(1,08+\frac{0,05}{2}\right)\times\frac{41\,000\cdot4,18(101+273)}{3600\cdot10,1\cdot273}=7,1$ |
| (27) Коэффициент теплоотдачи с воздушной стороны | $\alpha_2$ | (28) По номограмме III | (25) $\frac{ккал}{м^2\,час\,град}$ | 60,6 |
| (29) Коэффициент использования поверхности нагрева | $\xi$ | (30) По табл. номограммы VII | — | 0,75 |
| (31) Коэффициент теплопередачи | $k$ | $\xi\frac{\alpha_1\alpha_2}{\alpha_1+\alpha_2}$ | (25) $\frac{ккал}{м^2\,час\,град}$ | $0,75\frac{33,2\cdot60,6}{93,8}=16,1$ |
| (32) Температурный напор на входе газов | $\Delta t'$ | $\vartheta'-t''$ | °C | $255-173=82$ |
| (33) Температурный напор на выходе | $\Delta t''$ | $\vartheta''-t'$ | °C | $154-30=124$ |
| (34) Температурный напор при противотоке | $\Delta t_{прт}$ | $\frac{\Delta t'+\Delta t''}{2}$ | °C | $\frac{82+124}{2}=103$ |

Key: (1). Designation of value. (2). Designation. (3). Calculation formula or method of determination. (4). Dimensionality. (5). Calculation. (6). Temperature of air at output/yield. (7). It is accepted with subsequent refinement. (8). Enthalpy of theoretically necessary quantity of air with t''. (9). On is-table. (10). Ratio of quantity of air at output/yield from first stage to theoretically necessary. (10a). Kcal/kg. (11). Heat absorption of air on balance. (12). Mean temperature of air. (13). Enthalpy of theoretically necessary quantity of air at mean temperature. (14). Enthalpy of gases at output/yield from air preheater. (15). Temperature of gases at output/yield. (16). Mean temperature of gases. (17). Volume of gases on 1 kg of fuel/propellant. (18). On Tables 1. (19). nm³/kg. (20). Volume fraction of water vapors. (21). Average/mean gas velocity. (22). m/s. (23). Heat-transfer coefficient from gas side. (24). On nomogram. (25). kcal/m² hour deg. (26). Average/mean air speed. (27). Heat-transfer coefficient from air side. (28). On nomogram. (29). Coefficient of use of heating surface. (30). On tables of nomogram. (31). Coefficient of heat transfer. (32). Temperature head at entrance of gases. (33). Temperature head at output/yield. (34). Temperature head with countercurrent.

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Continued.

| (1) Наименование величины | (2) Обозначение | (3) Расчетная формула или способ определения | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| (6) Больший перепад температур | $\tau_б$ | $t''-t'$ | °C | 173—30=143 |
| (7) Меньший перепад температур | $\tau_м$ | $\vartheta'-\vartheta''$ | °C | 255—154=101 |
| (8) Параметр | $P$ | $\frac{\tau_м}{\vartheta'-t'}$ | — | $\frac{101}{255-30}=0,449$ |
| (9) Параметр | $R$ | $\frac{\tau_б}{\tau_м}$ | — | $\frac{143}{101}=1,41$ |
| (9) Коэффициент | $\psi$ | (10) По номограмме XV | — | 0,94 |
| (11) Температурный напор | $\Delta t$ | $\psi\Delta t_{прт}$ | °C | 0,94·103=97 |
| (12) Тепловосприятие воздухоподогревателя по уравнению теплопередачи | $Q_т$ | $\frac{kH\Delta t}{B_р}$ | (12) ккал/кг | $\frac{16,1\cdot 5420\cdot 97}{41000}=206$ |
| (13) Отношение значений тепловосприятия | — | $\frac{Q_т}{Q_б}\cdot 100$ | % | $\frac{206}{209}\cdot 100=98,5$ |

(14) Поскольку расхождение между $Q_б$ и $Q_т$ меньше 2%, расчет первой ступени воздухоподогревателя заканчивается.

(15) Так как невязка между промежуточными значениями температуры воздуха, определенными из расчета обеих ступеней воздухоподогревателя, превышает 10° С, необходимо произвести пересчет. Однако, поскольку определившееся из расчета значение температуры уходящих газов отличается от принятого меньше чем на 10° С, достаточно пересчитать только хвостовые поверхности нагрева.

### (16) Расчет второй ступени экономайзера (по ходу воды)

| | | | | |
|---|---|---|---|---|
| (17) Температура воды на входе во вторую ступень | $t'$ | (18) Принимается равной $t''$ первой ступени, определенной в основном расчете | °C | 240 |
| (19) Теплосодержание воды на входе в ступень | $i'$ | (20) Также по основному расчету | (12) ккал/кг | 248,2 |
| (21) Теплосодержание газов перед ступенью | $I'$ | (22) Из расчета перегревателя | » | 1261 |
| (23) Температура газов перед ступенью | $\vartheta'$ | (24) То же | °C | 620 |
| (25) Температура газов за ступенью | $\vartheta''$ | (26) Принимается с последующим уточнением | °C | 442 |
| (27) Теплосодержание газов за ступенью | $I''$ | (28) По $I\vartheta$-таблице | (12) ккал/кг | 890 |
| (29) Тепловосприятие ступени по балансу | $Q_б$ | $(I'-I''+\Delta\alpha I^0_{х.в})\varphi$ | » | (1261—890+1) 0,995=370 |
| (30) Теплосодержание воды на выходе из ступени | $i''$ | $i'+Q_б\frac{B_р}{D_{эк}}$ | » | $248,2+370\frac{41000}{230000}=314,2$ |
| (31) Температура воды на выходе из ступени | $t''$ | (32) По приложению II | °C | 295 |
| (33) Температурный напор на входе газов | $\Delta t'$ | $\vartheta'-t''$ | °C | 620—295=325 |
| (34) Температурный напор на выходе | $\Delta t''$ | $\vartheta''-t'$ | °C | 442—240=202 |
| (35) Средний температурный напор | $\Delta t$ | $\frac{\Delta t'+\Delta t''}{2}$ | °C | $\frac{325+202}{2}=263$ |

Key: (1). Designation of value. (2). Designation. (3). Calculation formula or method of determination. (4). Dimensionality. (5). Calculation. (6). Larger temperature differential. (7). Smaller temperature differential. (8). Parameter. (9). Coefficient. (10). On nomogram. (11). Temperature head. (12). Heat absorption of air preheater according to equation of heat transfer. (13). Relation of values of heat absorption. (14). Since disagreement between $Q_6$ and $Q_m$ less than 2o/o, calculation of first stage of air preheater is finished. (15). Since discrepancy between intermediate values of temperature of air, determined from calculation of both steps/stages of air preheater, exceeds 10°C, it is necessary to manufacture recalculation. However, since the determined of the calculation value of the temperature of stack gases differs from that accepted less than by 10°C, it suffices to count over only the tail heating surfaces. (16). Calculation of second step/stage of economizer (on course of water). (17). Temperature of water at entrance into second step/stage. (18). Is accepted equal to t'' first step/stage, determined in basic calculation. (19). Enthalpy of water at stage inlet. (20). Also on basis. (21). Enthalpy of gases before step/stage. (22). From calculation of superheater. (23). Temperature of gases before step/stage. (24). Then. (25). Temperature of gases after step/stage. (26). It is accepted with subsequent refinement. (27). Enthalpy of gases after step/stage. (28). On iθ-table. (29).

Heat absorption of step/stage on balance. (30). Enthalpy of water at output/yield from step/stage. (31). Temperature of water at output/yield from step/stage. (32). Temperature head at entrance of gases. (33). Temperature head at entrance of gases. (34). Temperature head at output/yield. (35). Average/mean temperature head.

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Continued.

| (1) Наименование величины | (2) Обозначение | (3) Расчетная формула или способ определения | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| (6) Тепловосприятие экономайзера по уравнению теплопередачи | $Q_т$ | $\frac{kH\Delta t}{B_p}$ | (7) ккал/кг | $\frac{62{,}0\cdot952\cdot263}{41\,000}=378$ |
| (8) Отношение значений тепловосприятия | — | $\frac{Q_т}{Q_б}\cdot100$ | % | $\frac{378}{370}\cdot100=102{,}0$ |

(9) Поскольку расхождение между $Q_б$ и $Q_т$ не превышает 2%, расчет на этом заканчивается.

(10) Расчет второй ступени воздухоподогревателя

| | | | | |
|---|---|---|---|---|
| (11) Температура газов на входе | $\vartheta'$ | (12) Из расчета второй ступени экономайзера | °C | 442 |
| (13) Теплосодержание газов на входе | $I'$ | (14) То же | (15) ккал/кг | 890 |
| (16) Температура воздуха на входе | $t'$ | (17) Принимается равной $t''$ первой ступени, определенной в основном расчете | °C | 173 |
| (18) Теплосодержание теоретически необходимого количества воздуха при $t'$ | $I_в^{0\prime}$ | (19) Также по основному расчету | (15) ккал/кг | 228 |
| (20) Температура воздуха на выходе | $t''$ | (21) Принимается с последующим уточнением | °C | 350 |
| (22) Теплосодержание теоретически необходимого количества воздуха при $t''$ | $I_в^{0\prime\prime}$ | (23) По $I\vartheta$-таблице | (15) ккал/кг | 467 |
| (24) Тепловосприятие второй ступени по балансу | $Q_б$ | $\left(\beta''_{вп}+\frac{\Delta\alpha_{вп\,II}}{2}\right)(I_в^{0\prime\prime}-I_в^{0\prime})$ | » | $\left(1{,}03+\frac{0{,}05}{2}\right)(467-228)=252$ |
| (25) Средняя температура воздуха в ступени | $t$ | $\frac{t'+t''}{2}$ | °C | $\frac{350+173}{2}=261$ |
| (26) Теплосодержание теоретически необходимого количества воздуха при $t$ | $I^0_{прс}$ | (23) По $I\vartheta$-таблице | (15) ккал/кг | 346 |
| (27) Теплосодержание газов за второй ступенью | $I''$ | $I'-\frac{Q_б}{\varphi}+\Delta\alpha_{вп\,II}I^0_{прс}$ | » | $890-\frac{252}{0{,}995}+17=654$ |
| (28) Температура газов за второй ступенью | $\vartheta''$ | (23) По $I\vartheta$-таблице | °C | 319 |
| (29) Температурный напор на входе газов | $\Delta t'$ | $\vartheta'-t''$ | °C | $442-350=92$ |
| (30) Температурный напор на выходе | $\Delta t'$ | $\vartheta''-t'$ | °C | $319-173=146$ |
| (31) Температурный напор при противотоке | $\Delta t_{прт}$ | $\frac{\Delta t'+\Delta t''}{2}$ | °C | $\frac{92+146}{2}=119$ |
| (32) Больший перепад температур | $\tau_б$ | $t''-t'$ | °C | $350-173=177$ |
| (33) Меньший перепад температур | $\tau_м$ | $\vartheta'-\vartheta''$ | °C | $442-319=123$ |
| (34) Параметр | $P$ | $\frac{\tau_м}{\vartheta'-t'}$ | — | $\frac{123}{442-173}=0{,}457$ |

Key: (1). Designation of value. (2). Designation. (3). Calculation formula or method of determination. (4). Dimensionality. (5). Calculation. (6). Heat absorption of economizer according to equation of heat transfer. (7). kcal/kg. (8). Relation of values of heat absorption. (9). Since disagreement between $Q_б$ and $Q_т$ does not exceed 2o/o, calculation on this is finished. (10). Calculation of secondary air heater. (11). Temperature of gases at entrance. (12). From calculation of second step/stage of economizer. (13). Enthalpy of gases at entrance. (14). Then. (15). kcal/kg. (16). Temperature of air at the inlet. (17). Is accepted equal to t'' first step/stage, determined in basic calculation. (18). Enthalpy of theoretically necessary quantity of air with t'. (19). Also according to basic calculation. (20). Temperature of air at output/yield. (21). It is accepted with the next refinement. (22). Enthalpy of theoretically necessary quantity of air with t''. (23). On iϑ-table. (24). Heat absorption of second step/stage on balance. (25). Mean temperature of air in step/stage. (26). Enthalpy of theoretically necessary quantity of air with t. (27). Enthalpy of gases after second step/stage. (28). Temperature of gases after second step/stage. (29). Temperature head at entrance of gases. (30). Temperature head at output/yield. (31). Temperature head with countercurrent. (32). larger temperature differential. (33). Smaller temperature differential. (34). Parameter.

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Continued.

| (1) Наименование величины | (2) Обозначение | (3) Расчетная формула или способ определения | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| (6) Параметр | $R$ | (7a) $\frac{\tau_б}{\tau_м}$ | — | $\frac{177}{123}=1,44$ |
| (7) Коэффициент | $\psi$ | По номограмме XV | — | 0,935 |
| (8) Температурный напор | $\Delta t$ | $\psi\Delta t_{прт}$ | °C | $0,935\cdot119=111$ |
| (9) Тепловосприятие по уравнению теплопередачи | $Q_т$ | $\frac{kH\Delta t}{B_р}$ | (10) ккал/кг | $\frac{17,5\cdot5\,420\cdot111}{41\,000}=257$ |
| (11) Отношение значений тепловосприятия | — | $\frac{Q_т}{Q_б}\cdot100$ | % | $\frac{257}{252}\cdot100=102$ |

(12) Поскольку расхождение между $Q_б$ и $Q_т$ не превышает 2%, расчет на этом заканчивается

(13) Расчет первой ступени экономайзера

| | | | | |
|---|---|---|---|---|
| (14) Температура газов на входе | $\vartheta'$ | (15) Из расчета второй ступени воздухоподогревателя | °C | 319 |
| (16) Теплосодержание газов на входе | $I'$ | (17) То же | (10) ккал/кг | 654 |
| (18) Теплосодержание воды на входе | $i'$ | (19) По основному расчету | » | 228,2 |
| (20) Температура воды на входе | $t'$ | (17) То же | °C | 222 |
| (21) Температура газов на выходе | $\vartheta''$ | (22) Принимается с последующим уточнением | °C | 257 |
| (23) Теплосодержание газов на выходе | $I''$ | (24) По $I\vartheta$-таблице | (10) ккал/кг | 530 |
| (25) Тепловосприятие первой ступени по балансу | $Q_б$ | $\varphi(I'-I''+\Delta\alpha I^0_{х.в})$ | » | $0,995(654-530+1)=124$ |
| (26) Теплосодержание воды на выходе | $i''$ | (28) $i'+Q_б\frac{B_р}{D_{эк}}$ | » | $228,2+124\frac{41\,000}{230\,000}=250,3$ |
| (27) Температура воды на выходе | $t''$ | По приложению II | °C | 242 |
| (29) Температурный напор на входе газов | $\Delta t'$ | $\vartheta'-t''$ | °C | $319-242=77$ |
| (30) Температурный напор на выходе | $\Delta t''$ | $\vartheta''-t'$ | °C | $257-222=35$ |
| (31) Температурный напор | $\Delta t$ | $\frac{\Delta t'-\Delta t''}{2,3\lg\frac{\Delta t'}{\Delta t''}}$ | °C | $\frac{77-35}{2,3\lg\frac{77}{35}}=53$ |
| (32) Тепловосприятие первой ступени по уравнению теплопередачи | $Q_т$ | $\frac{kH\Delta t}{B_р}$ | (10) ккал/кг | $\frac{55,2\cdot1\,720\cdot53}{41\,000}=123$ |
| (33) Отношение значений тепловосприятия | — | $\frac{Q_т}{Q_б}\cdot100$ | % | $\frac{123}{124}\cdot100=99$ |

(34) Поскольку расхождение между $Q_б$ и $Q_т$ меньше 2%, расчет экономайзера на этом заканчивается

(35) Расчет первой ступени воздухоподогревателя

| | | | | |
|---|---|---|---|---|
| (36) Температура газов на входе | $\vartheta'$ | (37) Из расчета первой ступени экономайзера | °C | 257 |
| (38) Теплосодержание газов на входе | $I'$ | (17) То же | (10) ккал/кг | 530 |

Key: (1). Designation of value. (2). Designation. (3). Calculation formula or method of determination. (4). Dimensionality. (5). Calculation. (6). Parameter. (7). Coefficient. (8). Temperature head. (9). Heat absorption according to equation of heat transfer. (10). kcal/kg. (11). Relation of values of heat absorption. (12). Since disagreement between $Q_б$ and $Q_т$ does not exceed 2o/o, calculation on this is finished. (13). Calculation of first stage of economizer. (14). Temperature of gases at entrance. (15). From calculation of secondary air heater. (16). Enthalpy of gases at entrance. (17). Then. (18). Enthalpy of water at entrance. (19). According to basic calculation. (20). Temperature of water at entrance. (21). Temperature of gases at output/yield. (22). It is accepted with subsequent refinement. (23). Enthalpy of gases at output/yield. (24). On iϑ-table. (25). Heat absorption of first stage on balance. (26). Enthalpy of water at output/yield. (27). Temperature of water at output/yield. (28). On appendix. (29). Temperature head at entrance of gases. (30). Temperature head at output/yield. (31). Temperature head. (32). Heat absorption of first stage according to equation of heat transfer. (33). Relation of values of heat absorption. (34). Since disagreement between $Q_б$ and $Q_т$ less than 2o/o, calculation of economizer on this is finished. (35). Calculation of first stage of air preheater. (36). Temperature of gases at entrance. (37). Of calculation of first stage of economizer. (38). Enthalpy of gases at entrance.

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| (1) Наименование величины | (2) Обозначение | (3) Расчетная формула или способ определения | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| (6) Температура воздуха на входе | $t'$ | (7) Принята | °C | 30 |
| (8) Теплосодержание теоретически необходимого количества воздуха при $t'$ | $I_в^{0'}$ | (9) По $I\vartheta$-таблице | (10) ккал/кг | 39,2 |
| (11) Температура воздуха на выходе | $t''$ | (12) Принимается с последующим уточнением | °C | 173 |
| (13) Теплосодержание теоретически необходимого количества воздуха при $t''$ | $I_в^{0''}$ | (9) По $I\vartheta$-таблице | (10) ккал/кг | 228 |
| (14) Тепловосприятие ступени по балансу | $Q_б$ | $\left(\beta''_{вп1}+\frac{\Delta\alpha_{вп1}}{2}\right)(I_в^{0''}-I_в^{0'})$ | » | $\left(1,08+\frac{0,05}{2}\right)(228-39,2)=209$ |
| (15) Средняя температура воздуха в ступени | $t$ | $\frac{t'+t''}{2}$ | °C | $\frac{173+30}{2}=101$ |
| (16) Теплосодержание теоретически необходимого количества воздуха при $t$ | $I^0_{прс}$ | (9) По $I\vartheta$-таблице | (10) ккал/кг | 132 |
| (17) Теплосодержание газов на выходе из воздухоподогревателя | $I_{ух}$ | $I'-\frac{Q_б}{\varphi}+\Delta\alpha I^0_{прс}$ | » | $530-\frac{209}{0,995}+7=327$ |
| (18) Температура газов на выходе | $\vartheta_{ух}$ | (9) По $I\vartheta$-таблице | °C | 156 |
| (19) Температурный напор на входе газов | $\Delta t'$ | $\vartheta'-t''$ | °C | 257—173=84 |
| (20) Температурный напор на выходе | $\Delta t''$ | $\vartheta''-t'$ | °C | 156—30=126 |
| (21) Температурный напор при противотоке | $\Delta t_{прт}$ | $\frac{\Delta t'+\Delta t''}{2}$ | °C | $\frac{84+126}{2}=105$ |
| (22) Больший перепад температур | $\tau_б$ | $t''-t'$ | °C | 173—30=143 |
| (23) Меньший перепад температур | $\tau_м$ | $\vartheta'-\vartheta''$ | °C | 257—156=101 |
| (24) Параметр | $P$ | $\frac{\tau_м}{\vartheta'-t'}$ | — | $\frac{101}{257-30}=0,445$ |
| (24) Параметр | $R$ | $\frac{\tau_б}{\tau_м}$ | — | $\frac{143}{101}=1,42$ |
| (25) Коэффициент | $\psi$ | (26) По номограмме XV | — | 0,94 |
| (27) Температурный напор | $\Delta t$ | $\psi\Delta t_{прт}$ | °C | 0,94·105=99 |
| (28) Тепловосприятие воздуха по уравнению теплопередачи | $Q_т$ | $\frac{kH\Delta t}{B_р}$ | (10) ккал/кг | $\frac{16,1\cdot 5\,420\cdot 99}{41\,000}=210$ |
| (29) Отношение значений тепловосприятия | — | $\frac{Q_т}{Q_б}\cdot 100$ | % | $\frac{210}{209}\cdot 100=100,5$ |

(30) На этом расчет первой ступени воздухоподогревателя заканчивается.

(31) Так как расхождение принятых и определившихся значений температур подогрева воздуха и уходящих газов, а также невязки между промежуточными значениями температур воды и воздуха, определенными из расчета обеих ступеней экономайзера и воздухоподогревателя, лежат в допустимых пределах, расчет котлоагрегата считается законченным. Необходимо только уточнить балансовые величины и проверить сходимость баланса

Key: (1). Designation of value. (2). Designation. (3). Calculation formula or method of determination. (4). Dimensionality. (5). Calculation. (6). Temperature of air at the inlet. (7). It is accepted. (8). Enthalpy of theoretically necessary quantity of air with t'. (9). On iϑ-table. (10). kcal/kg. (11). Temperature of air at output/yield. (12). It is accepted with subsequent refinement. (13). Enthalpy of theoretically necessary quantity of air with t''. (14). Heat absorption of step/stage or balance. (15). Mean temperature of air in step/stage. (16). Enthalpy of theoretically necessary quantity of air with t. (17). Enthalpy of gases at output/yield from air preheater. (18). Temperature of gases at output/yield. (19). Temperature head at entrance of gases. (20). Temperature head at output/yield. (21). Temperature head at output/yield. (22). Larger temperature differential. (23). Smaller temperature differential. (24). Parameter. (25). Coefficient. (26). On nomogram. (27). Temperature head. (28). Heat absorption of air according to equation of heat transfer. (29). Relation of values of heat absorption. 30). On this calculation of first stage of air preheater is finished. (31). Since disagreement of taken and determined values of temperatures of preheating air and stack gases, and also discrepancy between intermediate values of temperatures water and air, determined from calculation of both steps/stages of economizer and air preheater, lie/rest within permissible limits, calculation of boiler unit is considered completed. It is necessary to only make more precise balance values and to test the convergence of balance.

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Continued.

| (1) Наименование величины | (2) Обозначение | (3) Расчетная формула или способ определения | (4) Размерность | (5) Расчет |
|---|---|---|---|---|
| (6) Температура уходящих газов | $\vartheta_{yx}$ | (7) Из расчета первой ступени воздухоподогревателя | °C | 156 |
| (8) Теплосодержание уходящих газов | $I_{yx}$ | По $I\vartheta$-таблице | (10) ккал/кг | 327 |
| (11) Потеря тепла с уходящими газами | $q_2$ | $\frac{I_{yx}-\alpha_{yx}I^0_{x.в}}{Q^p_p}(100-q_4)$ | % | $\frac{(327-1{,}39\cdot 39{,}2)}{3\,650}\times\frac{100-2{,}5}{100}=7{,}3$ |
| (12) Сумма тепловых потерь[1] | $\Sigma q$ | $q_2+q_3+q_4+q_5+q_{6\,шл}$ | % | $7{,}3+0{,}5+2{,}5+0{,}5+0{,}1=10{,}9$ |
| (13) Коэффициент полезного действия агрегата | $\eta_{к.а}$ | $100-\Sigma q$ | % | $100-10{,}9=89{,}1$ |
| (14) Полный расход топлива (для расчетов топливоподачи и пылеприготовления) | $B$ | $\frac{Q_{к.а}\cdot 100}{Q^p_p\,\eta_{к.а}}$ | (15) кг/час | $\frac{136{,}3\cdot 10^6\cdot 100}{3\,650\cdot 89{,}1}=41\,900$ |
| (16) Расчетный расход топлива (действительно сгоревшего) для теплового и аэродинамического расчетов | $B_p$ | $B\,\frac{100-q_4}{100}$ | » | $41\,900\cdot 0{,}975=40\,800$ |
| (17) Полезное тепловыделение в топке | $Q_m$ | $Q^p_p\frac{100-q_3}{100}+\beta''_{вп}\cdot I^{0''}_в+(\Delta\alpha_m+\Delta\alpha_{пл.у})\,I^0_{х.в}$ | (10) ккал/кг | $3\,650\,\frac{100-0{,}5}{100}+1{,}03\cdot\times 467+0{,}17\cdot 39{,}2=4\,120$ |
| (18) Количество воспринятого в топке тепла[3] | $Q_л$ | $(Q_m-I''_m)\,\varphi$ | » | $(4\,120-2\,324)0{,}995=1\,787$ |
| (19) Расчетная невязка теплового баланса[3] | $\Delta Q$ | $Q^p_p\,\eta_{к.а}-(Q_л+Q_ф+Q_{пе\,II}+Q_{пе\,I}+Q_{эк\,II}+Q_{эк\,I})\,\frac{100-q_4}{100}$ | » | $3\,650\cdot 0{,}891-(1\,787+114+571+374+370+124)\frac{100-2{,}5}{100}=-5$ |
| (20) Относительная величина невязки | $\delta Q$ | $\frac{\Delta Q}{Q^p_p}\cdot 100$ | % | $\frac{5}{3\,650}\cdot 100=0{,}14$ |

(21) Так как невязка меньше 0,5% от $Q^p_p$ расчет котлоагрегата заканчивается

AD-A085 487 FOREIGN TECHNOLOGY DIV WRIGHT-PATTERSON AFB OH F/G 13/1

THERMAL DESIGN OF BOILER UNIT (STANDARD METHOD).(U)

APR 80

UNCLASSIFIED FTD-ID(RS)T-0411-80 NL



AD A085487

Key: (1). Designation of value. (2). Designation. (3). Calculation formula or method of determination. (4). Dimensionality. (5). Calculation. (6). Temperature of stack gases. (7). Of calculation of first stage of air preheater. (8). Enthalpy of stack gases. (9). On i$\vartheta$-table. (10). kcal/kg. (11). Heat loss with stack gases. (12). Sum of heat losses [1].

FOOTNOTE [1]. $q_3$, $q_4$, $q_5$ and $q_{6\,шл}$ are accepted according to the basic calculation. ENDFOOTNOTE.

(13). Efficiency of aggregate/unit. (14). Full rate of propellant flow (for calculations of fuel feed and pulverized coal preparation). (15). kg/h. (16). Calculated consumption of fuel (actually/really burned down) for thermal and aerodynamic designs. (17). Useful heat release in heating. (18). Quantity of taken in heating heat [2].

FOOTNOTE [2]. The enthalpy of gases at the output/yield from the heating is determined in the calculation of heating. ENDFOOTNOTE.

(19). Calculated discrepancy of heat balance [3]. ENDFOOTNOTE.

(20). Relative value of discrepancy. (21). Since discrepancy is less than 0.5o/o of $Q_p^p$ calculation of boiler unit is finished.

(1) Сводная таблица теплового расчета котла

| (3) Наименование величин | (4) Размерность | (2) Наименование газоходов | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | (5) Фестон | (6) II ступень перегревателя | (7) I ступень перегревателя | (8) Экономайзер, II ступень | (9) Воздухоподогреватель, II ступень | (10) Экономайзер, I ступень | (11) Воздухоподогреватель, I ступень |
| (12) Температура газов на входе | °C | 1 117 | 1 066 | 800 | 620 | 442 | 319 | 257 |
| (13) То же на выходе | (15) °C | 1 066 | 800 | 620 | 442 | 319 | 257 | 156 |
| (14) Тепловосприятие | ккал/кг | 116 | 571 | 374 | 370 | 252 | 124 | 209 |
| (16) Температура теплоносителя на входе | °C | 317 | 361 | 317 | 240 | 173 | 222 | 30 |
| (17) То же на выходе | °C | 317 | 510 | 361 | 295 | 350 | 242 | 173 |
| (18) Скорость газов | (19) м/сек | 6,5 | 8,3 | | 9,5 | 13,3 | 7,7 | 10,7 |
| (20) Скорости воды, пара, воздуха | » | — | 16,6 | | 1,06 | 9,5 | 1,14 | 7,1 |

Key: (1). The summary table of the thermal design of boiler. (2). Designation of flues. (3). Designation of values. (4). Dimensionality. (5). Scallop. (6). II step/stage of superheater. (7). I step/stage of superheater. (8). Economizer, II step/stage. (9). Air preheater, II step/stage. (10). Economizer, I step/stage. (11). Air preheater, I step/stage. (12). Temperature of gases at entrance. (13). Then at output/yield. (14). Heat absorption. (15). kcal/kg. (16). Temperature of heat-transfer agent at entrance. (17). Then at output/yield. (18). Gas velocity. (19). m/s. (20). Speeds of water, vapor, air.

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(a) РАСЧЕТНЫЕ ХАРАКТЕРИСТИКИ

| (b) Район месторождения | (c) Наименование месторождения | (d) Марка и сорт | (e) Рабочая масса топлива — (f) Состав, % | | | | | | | | (i) Низшая теплота сгорания |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $W^p$ | $A^p$ | $S^p_к$ | $S^p_{ор}$ | $C^p$ | $H^p$ | $N^p$ | $O^p$ | (k) $Q^p_н$, ккал/кг |
| (m) Ископаемые угли | | | | | | | | | | | |
| 1. Донецкий бассейн | — | Д | 13,0 | 19,6 | 2,4 | 1,6 | 50,6 | 3,7 | 1,1 | 8,0 | 4 840 |
| 2. „ „ | — | Г | 7,0 | 15,8 | 1,9 | 1,4 | 62,1 | 4,2 | 1,2 | 6,4 | 5 900 |
| 3. „ „ | — | ПЖ | 6,0 | 18,8 | 3,6 | | 62,4 | 3,8 | 1,1 | 4,3 | 5 980 |
| 4. „ „ | — | Т | 5,0 | 15,2 | 1,8 | 0,9 | 70,6 | 3,4 | 1,2 | 1,9 | 6 550 |
| 5. „ „ | — | ПА | 5,5 | 15,1 | 1,3 | 0,7 | 72,3 | 2,8 | 1,0 | 1,3 | 6 470 |
| 6. „ „ | — | АМ и АС | 5,0 | 13,3 | 1,0 | 0,7 | 76,4 | 1,5 | 0,8 | 1,3 | 6 500 |
| 7. „ „ | — | АРШ | 6,0 | 16,9 | 1,2 | 0,6 | 71,7 | 1,4 | 0,8 | 1,4 | 6 100 |
| 8. „ „ | — | АШ | 7,0 | 16,7 | 1,1 | 0,6 | 70,5 | 1,4 | 0,8 | 1,9 | 6 010 |
| 9. „ „ | — | ППМ | 11,0 | 40,1 | 3,3 | 0,5 | 38,6 | 2,6 | 0,8 | 3,1 | 3 650 |
| 10. „ „ | — | Шлам | 20,0 | 16,0 | 1,6 | 0,7 | 54,4 | 3,2 | 1,0 | 3,1 | 5 070 |
| 11. Кузнецкий бассейн | (11a) Анжеро-Судженское | ПС | 6,5 | 12,2 | 0,6 | | 74,0 | 3,5 | 1,5 | 1,7 | 6 740 |
| 12. „ „ | (12a) Кемеровское | К-ПС-СС | 9,0 | 15,5 | 0,5 | | 64,9 | 3,8 | 1,5 | 4,8 | 5 990 |
| 13. „ „ | „ | ПС-Т | 8,0 | 14,7 | 0,5 | | 70,0 | 3,3 | 1,5 | 2,0 | 6 360 |
| 14. „ „ | (14a) Ленинское | Д | 10,0 | 5,0 | 0,4 | | 67,2 | 4,7 | 2,0 | 10,7 | 6 300 |
| 15. „ „ | „ | Г | 9,0 | 10,9 | 0,6 | | 66,1 | 4,6 | 2,2 | 6,6 | 6 240 |
| 16. „ „ | (16a) Прокопьевско-Киселевское (Сталинуголь, Прокопьевскуголь, Кагановичуголь) | $СС^{**}_{26-35}$ | 7,0 | 7,4 | 0,4 | | 71,0 | 4,5 | 2,0 | 7,7 | 6 640 |
| 17. „ „ | (17a) То же | $СС^{**}_{18-25}$ | 6,0 | 10,3 | 0,4 | | 73,2 | 3,9 | 1,8 | 4,4 | 6 770 |
| 18. „ „ | „ „ | $СС^{**}_{11-17}$ | 5,0 | 11,4 | 0,4 | | 74,2 | 3,6 | 1,8 | 3,0 | 6 830 |
| 19. „ „ | (19a) Араличевское | Т | 7,0 | 16,7 | 0,6 | | 68,3 | 3,1 | 1,5 | 2,8 | 6 130 |
| 20. „ „ | — | ППС | 4,0 | 25,0 | 0,5 | | 60,4 | 3,6 | 1,8 | 4,7 | 5 660 |

480



| (g) Зольность на сухую массу $A^c$, % | (h) Максимальная (j) влажность $W^p_{макс}$, % | (k) зольность $A^c_{макс}$, % | (l) Влага аналитической пробы $W^a$, % | (m) Выход летучих на горючую массу $V^г$, % | (n) Теплота сгорания в бомбе $Q^г_б$, ккал/кг | (o) Температуры плавления золы: (p) начала деформации $t_1$, °C | (q) начала размягчения, $t_2$, °C | (r) начала жидкоплавкого состояния $t_3$, °C | (a) Характеристика нелетучего остатка |
|---|---|---|---|---|---|---|---|---|---|
| 22,5 | 20 | 30 | 4,5 | 43,0 | 7 730 | 1 050<br>950÷1 200 | 1 150<br>1 050÷>1 400 | 1 200<br>1 080÷>1 400 | (1a) Порошкообразный, слипшийся или спекшийся. |
| 17,0 | 12 | 25 | 3,0 | 39,0 | 8 100 | 1 050<br>950÷1 200 | 1 150<br>1 000÷1 300 | 1 220<br>1 050÷1 370 | (2a) Спекшийся, сплавленный, иногда вспученный |
| 20,0 | 10 | 30 | 1,0 | 32,0 | 8 400 | 1 100<br>1 000÷>1 400 | 1 120<br>1 050÷>1 400 | 1 200<br>1 150÷>1 400 | (3a) Спекшийся, сплавленный |
| 16,0 | 9 | 27 | 1,0 | 13,0 | 8 550 | 1 060<br>990÷1 170 | 1 230<br>1 040÷1 440 | 1 260<br>1 060÷1 470 | (4a) Порошкообразный, слипшийся или слабо спекшийся |
| 16,0 | 10 | 27 | 1,2 | 8,0 | 8 450 | 1 060<br>970÷1 120 | 1 240<br>1 070÷>1 500 | 1 290<br>1 100÷>1 500 | (5a) Порошкообразный |
| 14,0 | 8 | 25 | 2,0 | 4,0 | 8 150 | 1 060<br>970÷1 200 | 1 170<br>1 030÷1 400 | 1 200<br>1 050÷1 430 | (6a) То же |
| 18,0 | 10 | 27 | 2,0 | 4,0 | 8 130 | 1 070<br>930÷1 260 | 1 200<br>1 000÷1 450 | 1 250<br>1 040÷1 500 | (7a) » » |
| 18,0 | 10 | 30 | 2,0 | 4,0 | 8 090 | 1 070<br>980÷1 260 | 1 200<br>1 000÷1 450 | 1 250<br>1 040÷1 500 | (8a) » » |
| 45,0 | 15 | 50 | 1,0 | 30,0 | 8 050 | 1 000÷1 200 | 1 080÷1 420 | 1 140÷1 450 | (9a) Спекшийся |
| 20,0 | 30 | 30 | 1,0 | 30,0 | 8 500 | 1 000÷1 150 | 1 100÷1 350 | 1 150÷1 400 | (10a) То же |
| 13,0 | 10 | 18 | 1,0 | 15,0 | 8 600 | 1 150<br>1 050÷1 200 | 1 340<br>1 200÷1 500 | 1 440<br>1 250÷>1 500 | (11b) » » |
| 17,0 | 13 | 22 | 1,0 | 29,0<br>23÷31 | 8 300 | 1 090<br>1 030÷1 150 | 1 200<br>1 120÷1 300 | 1 240<br>1 160÷1 350 | (12b) » » |
| 16,0 | 11 | 26 | 1,0 | 16,0<br>11÷18 | 8 550 | 1 100<br>1 030÷1 140 | 1 240<br>1 120÷1 490 | 1 300<br>1 160÷>1 500 | (13a) Спекшийся или порошкообразный |
| 5,5 | — | — | 3,5 | 40,0 | 7 800 | 1 130<br>1 030÷1 260 | 1 200<br>1 050÷1 300 | 1 260<br>1 100÷1 400 | (14b) То же |
| 12,0 | 12 | 15 | 2,0 | 39,0 | 8 200 | 1 100<br>1 050÷1 250 | 1 200<br>1 100÷1 370 | 1 250<br>1 150÷1 430 | (15a) Спекшийся |
| 8,0 | 10 | 12 | 1,2 | 30<br>26÷35 | 8 100 | — | — | — | (16b) То же |
| 11,0 | 9 | 21 | 1,0 | 22<br>18÷25 | 8 400 | 1 100÷>1 500 | 1 240÷>1 500 | 1 280÷>1 500 | (17b) » » |
| 12,0 | 8 | 16 | 1,0 | 14,0<br>11÷17 | 8 450 | — | — | — | (18a) » » |
| 18,0 | 9 | 22 | 1,2 | 11,0 | 8 450 | 1 200<br>1 000÷1 350 | 1 360<br>1 260÷1 500 | 1 425<br>1 320÷>1 500 | (19b) Порошкообразный |
| 26,0 | 7 | 35 | 1,0 | 28<br>21÷31 | 8 300 | 1 090<br>1 000÷1 190 | 1 300<br>1 130÷1 500 | 1 350<br>1 180÷>1 500 | (20a) Спекшийся |

Key: (a). Design characteristics of solid and liquid propellants. (b). Region of fields. (c). Name of deposit. (d). Brand/mark and type. (e). Working mass of fuel/propellant. (f). Composition, o/o. (g). Ash content to dry mass. (h). Maximum. (i). Lowest heat of combustion. (j). humidity. (k). ash content. (l). Moisture of analytical test/sample. (m). output/yield of volatile components to combustible mass. (n). Heat of combustion in bomb kcal/kg. (o). Melting points of ash. (p). it began strains. (q). began softenings, $t_2$, with °C. (r). the beginning of fluid state. (s). Characteristic of nonvolatile remainder/residue. (t). kcal/kg. (u). Coal. (1). Donets basin. (1A). Powder-like, that fixed or sintered. (2a). Sintered, alloyed, sometimes distended. (3a). Sintered, alloyed. (4a). Powder-like, that fixed or weakly sintered. (5a). Powder-like. (6a). the same. (7a). the same. (8a). the same. (9a). Sintered. (10a). the same. (11). Kuznetsk Basin. (11a). Anzhero-Sudzhenskiy. (11b). the same. (12a). Kemerovo. (12b). the same. (13a). Sintered or powder-like. (14a). Leninist. (14b). the same. (15a). Sintered. (16a). Prokol'yevski-Kiselevskiy (Stalinugol', Prokop'yevskugol', Kaganovichugol'). (16b). the same (17a). the same. (17b). the same. (19a). Aralichevskiy. (19b). Powder-like. (20a). Sintered.

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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 21. Карагандинский бассейн | — | ПЖ-ПС | 7,5 | 25,0 | 0,8 | | 57,0 | 3,4 | 0,9 | 5,4 | 5 320 |
| 22. То же | — | Б | 26,0 | 17,0 | 0,6 | | 41,9 | 2,7 | 0,5 | 11,3 | 3 620 |
| 23. Подмосковный бассейн | — | Б | 33,0 | 23,5 | 1,7 | 1,2 | 29,1 | 2,2 | 0,6 | 8,7 | 2 510 |
| 24. Печорский бассейн | — | ПЖ | 7,0 | 18,6 | 0,4 | 0,5 | 62,5 | 3,9 | 1,7 | 5,4 | 5 930 |
| 25. » » | (26a) — | Д | 11,0 | 24,9 | 1,9 | 0,6 | 47,4 | 3,2 | 1,3 | 9,7 | 4 340 |
| 26. УССР Правобережье | Александрийское, Звенигородское, Коростышевское и др. (27a) | Б | 53,0 | 14,1 | 0,7 | 1,9 | 21,1 | 1,9 | 0,2 | 7,1 | 1 650 |
| 27. Западная Украина | Золочевское (Тростянецкое) | Б | 37,0 | 18,9 | 1,2 | 2,4 | 28,2 | 2,3 | 0,4 | 9,6 | 2 420 |
| 28. » » | Коломыйское (28a) (29a) | Б | 20,0 | 24,0 | 2,4 | 1,2 | 37,8 | 3,1 | 0,6 | 10,9 | 3 410 |
| 29. Закарпатская Украина | Мукачевское (Ильницкое) | Б | 45,0 | 24,8 | 0,4 | | 19,6 | 1,8 | 0,3 | 8,1 | 1 500 |
| 30. Башкирская АССР | Бабаевское (Ермолаевский разрез) (30a) | Б | 52,0 | 9,6 | 0,3 | 0,4 | 26,7 | 2,5 | 0,2 | 8,3 | 2 240 |
| 31. Урал | (31a) Кизеловское | Г | 5,5 | 29,3 | 3,2 | 1,9 | 50,9 | 3,7 | 0,8 | 4,7 | 4 970 |
| 32. » | » | Д | 5,5 | 26,5 | 4,6 | | 51,7 | 3,8 | 0,9 | 7,0 | 5 000 |
| 33. » | » | ППМ | 11,0 | 35,6 | 8,0 | 1,5 | 37,9 | 2,9 | 0,9 | 2,2 | 3 860 |
| 34. » | (34a) Богословское | Б | 28,0 | 21,6 | 0,3 | | 34,3 | 2,4 | 0,6 | 12,8 | 2 840 |
| 35. » | (35a) Челябинское | Б | 17,0 | 24,9 | 0,7 | 0,5 | 41,8 | 3,0 | 1,0 | 11,1 | 3 770 |
| 36. » | (36a) Буланашское | Г | 10,0 | 18,0 | 0,5 | 0,6 | 58,0 | 4,0 | 1,1 | 7,8 | 5 460 |
| 37. » | (37a) Егоршинское | А | 5,0 | 20,9 | 0,4 | | 66,7 | 2,7 | 1,0 | 3,3 | 5 880 |
| 38. Грузинская ССР | (38a) Ткварчельское | ПЖ | 10,0 | 34,2 | 1,3 | 0,5 | 44,1 | 3,3 | 0,9 | 5,7 | 4 180 |
| 39. » » | (39a) Ткибульское | Г | 11,0 | 26,7 | 0,7 | 0,7 | 48,0 | 3,6 | 0,9 | 8,4 | 4 470 |
| 40. » » | (40a) Гелати | Б | 11,0 | 40,1 | 1,5 | 0,5 | 34,2 | 2,5 | 0,7 | 9,5 | 3 070 |
| 41. » » | (41a) Ахалцихское | Б | 20,0 | 38,4 | 0,6 | 0,5 | 28,1 | 2,4 | 0,5 | 9,5 | 2 470 |
| 42. Казахская ССР | (42a) Иртышское (Экибастуз) | СС | 8,0 | 36,8 | 0,4 | 0,4 | 44,2 | 2,9 | 0,8 | 6,5 | 4 050 |
| 43. » » | (43a) Ленгеровское | Б | 27,0 | 14,6 | 1,3 | 0,8 | 44,4 | 2,6 | 0,4 | 8,9 | 3 850 |
| 44. Узбекская ССР | (44a) Ангрен | Б | 35,0 | 11,0 | 0,7 | 0,7 | 41,9 | 2,0 | 0,4 | 8,3 | 3 450 |
| 45. Киргизская ССР | (45a) Кызыл-Кия | Б | 27,0 | 11,7 | 1,4 | 0,4 | 46,0 | 2,6 | 0,6 | 10,3 | 4 000 |
| 46. » » | (46a) Сулюкта | Б | 21,0 | 11,9 | 0,5 | 0,1 | 51,7 | 2,7 | 0,5 | 11,6 | 4 400 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 27,0 | 12 | 32 | 2,0 | 28,0 | 8 250 | 1 150÷>1 500 | 1 400÷>1 500 | 1 450÷>1 500 | (21a) Спекшийся |
| 23,0 | 32 | 30 | 10,0 | 40,0 | 6 900 | 1 000<br>1 090÷1 120 | 1 200<br>1 160÷1 240 | 1 225<br>1 175÷1 270 | (22a) Порошкообразный |
| 35,0 | 37 | 45 | 8,0 | 45,0 | 6 650 | 1 350<br>1 000÷>1 500 | 1 500<br>1 050÷>1 500 | >1 500<br>1 100÷>1 500 | (23a) То же |
| 20,0 | 12 | 33 | 1,5 | 31,0 | 8 350 | 1 050<br>1 000÷1 150 | 1 225<br>1 100÷1 300 | 1 280<br>1 150÷1 400 | (24a) Спекшийся |
| 28,0 | 15 | 35 | 6,0 | 39,0 | 7 250 | 1 050<br>1 000÷1 125 | 1 130<br>1 060÷1 200 | 1 150<br>1 125÷1 240 | (25a) Порошкообразный |
| 30,0 | 60 | 40 | 10,0 | 60,0 | 6 400 | 1 050÷1 480 | 1 100÷>1 500 | 1 130÷>1 500 | (26b) То же |
| 30,0 | 45 | 40 | 9,0 | 57,0 | 6 450 | 1 050<br>1 000÷1 100 | 1 120<br>1 060÷1 180 | 1 150<br>1 090÷1 210 | » » |
| 30,0 | — | — | 10,0 | 53,0 | 6 700 | 1 030 | 1 050 | 1 070 | » » |
| 45,0 | — | — | 9,0 | 60,0 | 6 200 | 1 120<br>1 000÷1 210 | 1 280<br>1 200÷1 390 | 1 310<br>1 230÷1 410 | » » |
| 20,0 | 60 | 30 | 7,0 | 63,0 | 7 050 | 1 120<br>1 000÷1 200 | 1 200<br>1 150÷1 250 | 1 220<br>1 170÷1 260 | » » |
| 31,0 | 10 | 40 | 1,2 | 44,0 | 8 150 | 1 150<br>960÷1 470 | 1 410<br>1 150÷>1 500 | 1 450<br>1 200÷>1 500 | (21a) Спекшийся |
| 28,0 | 10 | 37 | 1,5 | 45,0 | 7 850 | 1 130<br>990÷1 220 | 1 410<br>1 300÷>1 500 | 1 440<br>1 350÷>1 500 | (32a) Порошкообразный или слабо спекшийся |
| 40,0 | 15 | 45 | 1,0 | 44,0 | 8 000 | 1 000* | 1 140* | 1 170* | (21a) Спекшийся |
| 30,0 | 33 | 35 | 11,0 | 48,0 | 6 250 | 1 150<br>1 050÷>1 500 | 1 350<br>1 100÷>1 500 | 1 400<br>1 130÷>1 500 | (22a) Порошкообразный |
| 30,0 | 24 | 40 | 9,0 | 43,0 | 7 000 | 1 050<br>1 000÷1 150 | 1 160<br>1 100÷1 350 | 1 220<br>1 150÷1 400 | (26b) То же (23a) |
| 20,0 | 15 | — | 2,5 | 40,0 | 8 000 | 1 200 | 1 275 | 1 300 | Слабо спекшийся |
| 22,0 | 9 | 30 | 1,3 | 9,0 | 8 200 | >1 500<br>1 350÷>1 500 | >1 500 | >1 500 | (25a) Порошкообразный |
| 38,0 | 14 | 45 | 1,2 | 40,0 | 8 000 | 1 450<br>1 400÷>1 500 | >1 500 | >1 500 | (36b) Слабо спекшийся |
| 30,0 | 15 | 40 | 3,5 | 43,0 | 7 650 | 1 450<br>1 300÷>1 500 | 1 500<br>1 350÷>1 500 | >1 500<br>1 370÷>1 500 | (21a) Спекшийся |
| 45,0 | — | — | 7,5 | 43,0 | 6 800 | >1 500 | — | — | (32a) Порошкообразный |
| 48,0 | — | — | 11,0 | 49,0 | 6 600 | 1 290 | 1 380 | 1 400 | (23a) То же |
| 40,0 | — | — | 1,3 | 32,0 | 7 750 | 1 300÷>1 400 | 1 375÷>1 500 | 1 450÷>1 500 | Порошкообразный или слабо спекшийся (32a) |
| 20,0 | 33 | 27 | 8,0 | 40,0 | 7 200 | 1 020<br>1 000÷1 050 | 1 100<br>1 050÷1 200 | 1 150<br>1 050÷1 270 | (22a) Порошкообразный |
| 17,0 | 40 | 25 | 9,0 | 34,0 | 7 050 | 1 120<br>1 040÷1 240 | 1 210<br>1 100÷1 360 | 1 240<br>1 130÷1 375 | (23a) То же |
| 16,0 | 32 | 21 | 10,0 | 38,0 | 7 100 | 1 050<br>1 000÷1 250 | 1 100<br>1 030÷1 300 | 1 150<br>1 050÷1 350 | » » |
| 15,0 | 25 | 20 | 10,0 | 36,0 | 7 000 | 1 130<br>1 030÷1 300 | 1 250<br>1 120÷1 360 | 1 280<br>1 180÷1 380 | » » |

Key: (21). Karaganda basin. (21a). Sintered. (22). the same. (22a). Powder-like. 23. Moscow basin. (23a). the same. 24. Pechora basin. (24a). Sintered. 25. Pechora basin. (25a). Powder-like. 26. UkrSSR [ - Ukrainian SSR] right bank. (26a). Alexandrine, Svenigorodskiy, Korostyshevskiy, etc. (26b). the same. 27. Western Ukraine. (27a). Zolochevskiy (Trostyanetskiy). (28a). Kolomyyskoye. (29). Transcarpathian Ukraine. (29a). Mukachevskiy (Il'nitskiy). (30). Bashkir ASSR. (30a). Babayevskiy (Yermolayevskiy section/cut). (31). Urals. (31a). Kizelovskiy. (32a). Powder-like or weakly sintered. (33a). Kizelovskiy. (35a). Chelyabinsk. (36a). Bulanashkiy. (36b). Weakly sintered. (37a). Yegorshinskiy. (38). Georgian SSR. (38a). Tkvarchel'skiy. (39a). Tkbivul'skiy. (40a). Gelati. (41a). Akhaltsikhskiy. 42. Kazakh SSR. (42a). Irtysh (Ekibastuz). (43a). Lengerovskiy. 44. Uzbek SSR. (44a). Angren. (45). Kirghiz SSR. (45a). Kyzyl-Kiya. (46a). Sulyukta.

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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 47. Киргизская ССР | (47a) Кок-Янгак | Д | 15,0 | 17,0 | 1,2 | 0,4 | 52,7 | 3,5 | 0,7 | 9,5 | 4 850 |
| 48. » » | (48a) Ташкумыр | Д | 13,0 | 11,3 | 0,8 | | 59,4 | 3,8 | 0,9 | 10,8 | 5 450 |
| 49. Таджикская ССР | (49a) Шураб | Б | 26,0 | 12,6 | 0,7 | | 46,7 | 2,5 | 0,5 | 11,0 | 3 950 |
| 50. Красноярский край | (50a) Канское (Ирша-Бородинское) | Б | 32,0 | 10,2 | 0,3 | 0,2 | 41,6 | 2,9 | 0,8 | 12,0 | 3 570 |
| 51. Хакасская А. О. | Минусинское (51a) | Д | 13,0 | 10,4 | 0,2 | 0,4 | 67,9 | 4,8 | 1,9 | 1,4 | 6 340 |
| 52. Иркутская обл. | (52a) Черемховское | Д | 14,0 | 21,5 | 0,5 | 0,5 | 50,0 | 3,7 | 1,0 | 8,8 | 4 660 |
| 53. Бурят-Монгольская АССР | (53a) Гусино-Озерское | Б | 21,0 | 15,8 | 0,6 | | 47,4 | 3,2 | 0,6 | 11,4 | 4 240 |
| 54. Читинская обл. | (54a) Тарбагатайское | Б | 25,0 | 13,5 | 3,1 | 0,6 | 45,5 | 3,1 | 0,8 | 8,4 | 4 050 |
| 55. » » | (55a) Черновское | Б | 33,0 | 7,4 | 0,5 | | 44,7 | 3,0 | 0,8 | 10,6 | 3 910 |
| 56. » » | (56a) Арабагарское | Б | 25,0 | 15,0 | 0,2 | 0,5 | 42,6 | 2,9 | 0,8 | 13,0 | 3 720 |
| 57. » » | (57a) Букачачинское | Г | 8,0 | 12,0 | 0,6 | | 65,6 | 4,4 | 0,9 | 8,5 | 6 140 |
| 58. » » | | Д | 12,0 | 10,0 | 0,5 | | 60,8 | 4,3 | 0,9 | 11,5 | 5 610 |
| 59. Хабаровский край | (59a) Райчихинское | Б | 37,0 | 9,5 | 0,2 | | 37,8 | 2,3 | 0,5 | 12,7 | 3 070 |
| 60. » » | (60a) Кивдинское | Б | 37,0 | 13,2 | 0,2 | | 38,8 | 2,1 | 0,6 | 8,1 | 2 840 |
| 61. » » | (61a) Ургальское (Бурея) | Г | 5,0 | 31,4 | 0,3 | | 50,9 | 3,8 | 0,8 | 7,8 | 4 860 |
| 62. Приморский край | (62a) Сучанское | Г* | 7,0 | 27,9 | 0,5 | | 54,7 | 3,4 | 0,9 | 5,6 | 5 030 |
| 63. » » | » | ПЖ | 6,0 | 21,6 | 0,4 | | 61,9 | 3,6 | 1,0 | 5,5 | 5 720 |
| 64. » » | » | Т | 6,0 | 23,5 | 0,4 | | 63,5 | 2,8 | 0,7 | 3,1 | 5 720* |
| 65. » » | (65a) Артемовское | Б | 28,0 | 21,6 | 0,3 | | 35,5 | 2,9 | 0,8 | 10,9 | 3 120 |
| 66. » » | (66a) Тавричанское | Б | 14,0 | 21,5 | 0,5 | | 47,7 | 3,5 | 1,0 | 11,8 | 4 350 |
| 67. » » | (67a) Подгородненское | Т | 5,0 | 38,0 | 0,3 | | 49,9 | 2,6 | 0,6 | 3,6 | 4 520 |
| 68. » » | (68a) Ворошиловское | СС | 5,0 | 39,9 | 0,2 | | 46,3 | 3,0 | 0,6 | 5,0 | 4 310 |
| 69. » » | (69a) Липовецкое | Д | 8,5 | 27,5 | 0,3 | | 48,6 | 3,8 | 0,6 | 10,7 | 4 530 |

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 20,0 | 18 | 25 | 6,0 | 37,0 | 7 600 | 1 100<br>1 000÷>1 500 | 1 250<br>1 080÷>1 500 | 1 350<br>1 100÷>1 500 | 32a Порошкообразный или слабо спекшийся |
| 13,0 | 18 | 20 | 6,0 | 37,0 | 7 600 | 1 200<br>1 050÷1 500 | 1 300<br>1 150÷>1 500 | 1 350<br>1 170÷>1 500 | То же 23a |
| 17,0 | 32 | 25 | 11,0 | 35,0 | 6 900 | 1 120<br>1 050÷1 350 | 1 200<br>1 100÷1 400 | 1 230<br>1 130÷1 420 | 25a Порошкообразный |
| 15,0 | 37 | 25 | 11,0 | 49,0 | 6 800 | 1 150<br>1 000÷1 300 | 1 250<br>1 100÷1 375 | 1 270<br>1 130÷1 400 | То же 23a |
| 12,0 | 20 | 20 | 3,5 | 42,0 | 7 700 | 1 150<br>1 100÷1 200 | 1 300<br>1 200÷1 350 | 1 350<br>1 280÷1 380 | 24a Спекшийся |
| 25,0 | 18 | 30 | 4,0 | 45,0 | 7 700 | 1 130<br>1 000÷>1 500 | 1 240<br>1 100÷>1 500 | 1 275<br>1 120÷>1 500 | То же 23a |
| 20,0 | 25 | 30 | 5,0 | 43,0 | 7 200 | 1 050<br>1 000÷1 160 | 1 160<br>1 050÷1 350 | 1 220<br>1 070÷1 380 | Порошкообразный 25a |
| 18,0 | 30 | 25 | 8,0 | 43,0 | 7 150 | 1 050<br>1 000÷1 120 | 1 200<br>1 040÷1 330 | 1 240<br>1 050÷1 450 | То же 23a |
| 11,0 | 40 | 18 | 11,0 | 42,0 | 7 200 | 1 050<br>1 030÷1 080 | 1 150<br>1 100÷1 200 | 1 200<br>1 130÷1 280 | » » |
| 20,0 | 30 | 30 | 11,0 | 45,0 | 6 750 | 1 070<br>1 000÷1 130 | 1 160<br>1 150÷1 175 | 1 210<br>1 160÷1 260 | » » |
| 13,0 | 12 | 20 | 3,0 | 38,0 | 8 050 | 1 200<br>1 050÷1 400 | 1 300<br>1 150÷1 500 | 1 350<br>1 170÷>1 500 | Спекшийся 24a |
| 11,0 | 17 | 15 | 5,0 | 42,0 | 7 600 | 1 050<br>1 000÷1 110 | 1 150<br>1 100÷1 250 | 1 170<br>1 120÷1 270 | 32a Порошкообразный или слабо спекшийся |
| 15,0 | 45 | 21 | 10,5 | 43,0 | 6 400 | 1 090<br>1 000÷1 180 | 1 240<br>1 130÷1 300 | 1 275<br>1 200÷1 310 | 25a Порошкообразный |
| 21,0 | 42 | 30 | 10,5 | 41,0 | 6 400 | 1 050<br>1 040÷1 060 | 1 200<br>1 100÷1 250 | 1 250<br>1 200÷1 300 | То же 23a |
| 33,0 | 8 | 40 | 1,5 | 42,0 | 8 000 | 1 370<br>1 100÷>1 500 | >1 500<br>1 400÷>1 500 | >1 500<br>1 450÷>1 500 | Спекшийся 24a |
| 30,0 | — | — | 2,0 | 35,0 | 8 100 | — | — | — | То же 23a |
| 23,0 | 10 | 30 | 1,5 | 29,0 | 8 250 | 1 130<br>1 050÷1 22[illegible] | 1 300<br>1 250÷1 500 | 1 350<br>1 200÷>1 500 | Спекшийся, сплавленный 63a |
| 25,0 | 10 | 30 | 1,0 | 11,0 | 8 400 | 1 100* | 1 250* | 1 280* | 25a Порошкообразный |
| 30,0 | 32 | 35 | 9,0 | 49,0 | 6 850 | 1 125<br>1 0[illegible]÷1 350 | 1 240<br>1 110÷1 450 | 1 280<br>1 125÷1 475 | То же 23a |
| 25,0 | 17 | 30 | 8,5 | 45,0 | 7 200 | [illegible]175<br>1 05[illegible]÷1 400 | 1 350<br>1 100÷>1 500 | 1 400<br>1 200÷>1 500 | » » |
| 40,0 | — | — | 1,0 | 17,0 | 8 250 | 1 [illegible]0<br>1 050÷1 420 | 1 400<br>1 230÷>1 500 | 1 430<br>1 270÷>1 500 | Слипшийся 62b |
| 42,0 | — | — | 0,7 | 25,0 | 8 200 | 1 4[illegible]<br>1 300÷>1 500 | >1 500 | >1 500 | Спекшийся 24a |
| 30,0 | — | — | 3,0 | 50,0 | 7 500 | — | — | — | Слабо спекшийся 36b |

Key: (47). Kirghiz SSR. (47a). Kok-Yangagk. (48a). Tashkumyr. (49). Tadzhik SSR. (49a). Shurab. (50). Krasnoyarsk edge. (50a). Kanskiy (Irsha-Borodinskiy). (51). A. O. Khakasskaya. (51a). Minusinsk. (52). Irkutsk Oblast'. (52a). Cheremkhovskiy. (53). Buryat Mongolian ASSR. (53a). Gusino-Ozerskiy. (54). Chita Oblast'. (54a). Tarbagatayskiy. (55a). Chernovskiy. (56a). Arabagarskiy. (57a). Bukachachinskiy. (59). Khabarovsk edge. (59a). Raychikhinskiy. (60a). Kivdinskiy. (61a). Ural'skiy (Bureya). (62). Seaside edge. (62a). Suchanskiy. (63a). Sintered, alloyed. (65a). Artemovskiy. (66a). Tavrichanskiy. (67a). Podgorodnenskiy. (67b). Fixing. (68a). Voroshilovskiy. (69a). Lipovetskiy.

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Continuation RN2-01.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| (v) **Горючие сланцы** | | | | | | | | | | | |
| 70. Эстонская ССР | — | — | 15,0 | 37,4[1] +13,8 | 1,1 | 0,4 | 25,0 | 3,2 | 0,1 | 4,0 | 2 720[2] |
| 71. Ленинградская обл. | (71a) Гдовское | — | 15,0 | 43,8[1] +14,9 | 1,0 | 0,3 | 19,3 | 2,5 | 0,1 | 3,1 | 2 080[2] |
| 72. Куйбышевская обл. | (72a) Кашпирское | — | 20,0 | 45,8[1] +9,6 | 1,8 | 1,8 | 15,0 | 1,8 | 0,3 | 3,9 | 1 510[2] |
| 73. Саратовская обл. | (73a) Савельевское | — | 20,0 | 48,7[1] +8,0 | 1,2 | 1,7 | 14,2 | 1,8 | 0,3 | 4,1 | 1 430[2] |
| 74. » | (74a) Озинское | | 21,0 | 49,5[1] +55 | 1,3 | 1,2 | 14,6 | 1,9 | 0,4 | 4,6 | 1 470[2] |
| 75. **Торф** | — | (75a) Кусковой | 40,0 | 6,6 | 0,2 | | 30,9 | 3,2 | 1,3 | 17,8 | 2 560 |
| 76. » | — | (76a) Фрезерный | 50,0 | 5,5 | 0,1 | | 25,7 | 2,7 | 1,1 | 14,9 | 2 030 |
| 77. **Дрова** | — | — | 40,0 | 0,6 | — | | 30,3 | 3,6 | 0,4 | 25,1 | 2 440 |
| 78. **Коксовая мелочь** | — | — | 20,0 | 12,0 | 1,1 | | 62,6 | 1,4 | 1,0 | 1,9 | 5 220 |
| 79. **Мазут** | — | (79a) Малосернистый | 3,0 | 0,3 | 0,5 | | 85,3 | 10,2 | 0,7 | | 9 310 |
| 80. » | — | (80a) Высокосернистый | 3,0 | 0,3 | 2,9 | | 83,4 | 10,0 | 0,4 | | 9 170 |
| **Ископаемые угли новых месторождений** | | | | | | | | | | | |
| 81. Западная Украина | (81a) Львовско-Волынское | Г | 10,5 | 22,4 | 0,5 | 0,5 | 54,0 | 3,5 | 0,9 | 7,7 | 4 950 |
| 82. Казахская ССР | (82a) Кушмурунское | Б | 35,0 | 13,0 | 1,5 | | 37,7 | 2,8 | 0,6 | 9,4 | 3 230 |
| 83. Кемеровская обл. | (83a) Итатское | Б | 45,0 | 8,3 | 0,6 | | 32,9 | 2,3 | 0,3 | 10,6 | 2 675 |
| 84. Красноярский край | (84a) Назаровское | Б | 40,0 | 7,2 | 0,6 | | 37,2 | 2,6 | 0,4 | 12,0 | 3 060 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 46,0[1]<br>+16,2 | 18 | 50[1]<br>+18 | 0,6 | 90,0 | 8 940[2] | 1 220<br>1 150÷1 400 | 1 400<br>1 275÷>1 500 | 1 430<br>1 300÷>1 500 | 22a<br>Порошкообразный |
| 53,5[1]<br>+17,5 | 18 | 55[1]<br>+20 | 0,6 | 90,0 | 8 870[2] | 1 250<br>1 140÷1 430 | 1 360<br>1 220+>1 500 | 1 375<br>1 230+>1 500 | 23a То же |
| 61,0[1]<br>+12,0 | 25 | 65[1]<br>+13 | 3,0 | 80,0 | 7 210[2] | 1 050<br>980÷1 090 | 1 120<br>1 020÷1 170 | 1 140<br>1 040÷1 180 | • • |
| 64,0[1]<br>+10,0 | 25 | 65[1]<br>+13 | 3,0 | 80,0 | 7 200[2] | 1 120<br>1 000÷1 320 | 1 200<br>1 060÷1 390 | 1 230<br>1 140÷1 400 | • • |
| 65,0[1]<br>+7,0 | 25 | 68[1]<br>+9 | 3,0 | 80,0 | 7 180[2] | 1 075* | 1 170* | 1 190* | • • |
| 11,0 | 53 | — | 11,0 | 70,0 | 5 580 | 800÷1 400 | 1 000÷1 500 | 1 010+>1 500 | • • |
| 11,0 | 55 | — | 1[illegible],0 | 70,0 | 5 580 | 800÷1 400 | 1 000÷1 500 | 1 010+>1 500 | • • |
| 1,0 | 45 | — | 7,0 | 85,0 | 4 850 | — | — | — | Слипшийся, рыхлый |
| 15,0 | 30 | 30 | 1,0 | 6,0 | 8 000 | — | — | — | Порошкообразный |
| 0,3 | — | — | — | — | 10 210 | — | — | — | |
| 0,3 | — | — | — | — | 10 060 | — | — | — | |
| 25,0 | — | — | 2,5 | 38,5 | 7 800 | 1 100 | 1 180 | 1 210 | От порошкообразного до слипшегося |
| 20,0 | — | — | 9,0 | 50,0 | 7 000 | 1 070 | 1 155 | 1 185 | Порошкообразный |
| 15,0 | — | — | 9,0 | 49,0 | 6 600 | 1 150 | 1 270 | 1 280 | То же |
| 12,0 | — | — | 11,0 | 48,0 | 6 550 | 1 250 | 1 350 | 1 360 | |

FOOTNOTE 1. First term - ash, the second - carbonic acid of carbonates.

2. Heat of combustion for schists is given without taking into account negative thermal effect of expansion of carbonates.

3. Indications in accordance with recalculation of propellant

properties from one mass to another see pp. 2-05 and 2-06.

* Data given according to the unit analyses. Chain wheel in the designation of deposit or brand/mark indicates the fact that all propellant properties are given in the limited quantity of data.

** Numerals in the designation of brand/mark indicate the output/yield of voltaliles w, o/c.

Key: (v). The bituminous shale. (70). Estonian. (71). Leningrad Obl. (71a). Gdovskiy. (72). Kuybyshev Obl. (72a). Kashpirskiy. (73). Saratov Obl. (73a). Savel'yevskiy. (74a). Ozinskiy. (75). Peat. (75a). Cake. (76a). Milling. (77). Firewood. (77a). Fixed, loose. (78). Coke breeze. (79). Petroleum residue. (79a). Low-sulfur. (80). Coal of new deposits. (80a). High-sulphur. (80). Western Ukraine. (81a). L'vov-Volyn. (81b). From the powder-like to that fixing. (82). Kazakh SSR. (82a). Kushmurunskiy. (83). Kemerovo Obl. (83a). Itatskiy. (84). Krasnoyarsk edge. (84a). Nazarovskiy.

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## (a) РАСЧЕТНЫЕ ХАРАКТЕРИСТИКИ ГАЗООБРАЗНЫХ ТОПЛИВ

РН 2-02

| (b) Наименование газа | (c) Состав газа в процентах по объему | | | | | | | | | | | | (e) Теплота сгорания низшая сухого газа $Q_н^c$, ккал/нм³ | (f) Вес нормального кубометра $\gamma_{г.тл}^c$, кг/нм³ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $H_2S$ | $CO_2$ | (d) Непредельные углеводороды | $O_2$ | CO | $H_2$ | $CH_4$ | $C_2H_6$ | $C_3H_8$ | $C_4H_{10}$ | $C_5H_{12}$ | $N_2$ | | |
| **I. Газ доменных печей** | | | | | | | | | | | | | | |
| 1. Древесноугольных | — | 12,0 | — | — | 27,0 | 8,0 | 1,6 | — | — | — | — | 51,4 | 1 157 | 1,238 |
| 2. Коксовых | 0,3 | 10,2 | — | — | 28,0 | 2,7 | 0,3 | — | — | — | — | 58,5 | 957 | 1,296 |
| **II. Генераторный газ** | | | | | | | | | | | | | | |
| *Из кускового топлива* | | | | | | | | | | | | | | |
| 3. Коксовая мелочь | 0,2 | 5,0 | — | 0,2 | 28,5 | 13,0 | 0,7 | — | — | — | — | 52,4 | 1 265 | 1,136 |
| 4. Антрацит донецкий | 0,2 | 5,5 | — | 0,2 | 27,5 | 13,5 | 0,5 | — | — | — | — | 52,6 | 1 230 | 1,135 |
| 5. Сулюктинский уголь | 0,2 | 5,0 | 0,1 | 0,2 | 29,0 | 14,6 | 0,8 | — | — | — | — | 50,1 | 1 343 | 1,116 |
| 6. Богословский „ | — | 8,0 | 0,3 | 0,2 | 24,0 | 13,6 | 2,2 | — | — | — | — | 51,7 | 1 303 | 1,142 |
| 7. Газовый донецкий уголь | 0,3 | 5,0 | 0,3 | 0,2 | 26,5 | 13,5 | 2,3 | — | — | — | — | 51,9 | 1 402 | 1,122 |
| 9. Лисичанский уголь | 1,0 | 7,0 | 0,3 | 0,2 | 25,0 | 15,0 | 2,5 | — | — | — | — | 49,0 | 1 451 | 1,119 |
| 9. Черемховский „ | 0,1 | 7,0 | 0,4 | 0,2 | 25,5 | 15,5 | 2,6 | — | — | — | — | 48,7 | 1 452 | 1,110 |
| 10. Челябинский „ | 0,2 | 5,0 | 0,2 | 0,2 | 30,0 | 13,0 | 2,0 | — | — | — | — | 49,4 | 1 449 | 1,128 |
| 11. Подмосковный „ | 1,2 | 6,5 | 0,3 | 0,2 | 25,0 | 14,0 | 2,2 | — | — | — | — | 50,6 | 1 411 | 1,130 |
| 12. Торф машиноформовочный | 0,1 | 8,0 | 0,4 | 0,2 | 28,0 | 15,0 | 3,0 | — | — | — | — | 45,3 | 1 548 | 1,121 |
| 13. Гидроторф | 0,1 | 8,5 | 0,4 | 0,2 | 27,5 | 15,0 | 2,5 | — | — | — | — | 45,8 | 1 491 | 1,127 |
| 14. Древесина (щепа) | — | 6,5 | 0,4 | 0,2 | 29,0 | 14,0 | 3,0 | — | — | — | — | 46,9 | 1 547 | 1,122 |
| *Из мелкозернистого топлива (0÷6 мм)* | | | | | | | | | | | | | | |
| *(газификация во взвешенном слое)* | | | | | | | | | | | | | | |
| 15. Фрезерный торф* | — | 9,8 | 0,7 | 0,2 | 20,3 | 10,9 | 1,9 | — | — | — | — | 56,2 | 1 154 | 1,188 |
| 16. Подмосковный уголь* | 0,4 | 6,9 | 0,4 | 0,2 | 21,7 | 7,1 | 1,1 | — | — | — | — | 62,2 | 1 010 | 1,217 |
| **III. Водяной газ[1]** | | | | | | | | | | | | | | |
| 17. Из кокса | 0,3 | 6,5 | — | 0,2 | 37,0 | 50,0 | 0,5 | — | — | — | — | 5,5 | 2 466 | 0,715 |
| 18. „ антрацита | 0,5 | 6,0 | — | 0,2 | 38,5 | 48,0 | 0,5 | — | — | — | — | 6,3 | 2 471 | 0,736 |
| **IV. Газ воздушной продувки при получении водяного газа** | | | | | | | | | | | | | | |
| 19. Из кокса | 0,1 | 17,5 | — | 0,2 | 5,0 | 1,3 | — | — | — | — | — | 75,9 | 190 | 1,366 |
| 20. „ антрацита | 0,1 | 14,5 | — | 0,2 | 8,8 | 2,3 | 0,2 | — | — | — | — | 73,9 | 348 | 1,332 |
| **V. Газ подземной газификации** | | | | | | | | | | | | | | |
| 21. Из каменного угля | 0,6 | 10,3 | — | 0,2 | 18,4 | 11,1 | 1,8 | — | — | — | — | 57,6 | 1 027 | 1,191 |
| 22. „ подмосковного угля | 0,6 | 9,5 | — | — | 10,0 | 14,5 | 1,8 | — | — | — | — | 63,6 | 861 | 1,146 |
| **VI. Газ коксовых печей** | | | | | | | | | | | | | | |
| 23. Очищенный | 0,4 | 2,3 | 1,9 | 0,8 | 6,8 | 57,5 | 22,5 | — | — | — | — | 7,8 | 3 958 | 0,483 |
| 24. Неочищенный | 0,4 | 2,3 | 2,7[2] | 0,8 | 6,8 | 57,0 | 22,3 | — | — | — | — | 7,7 | 4 196 | 0,507 |
| **VII. Газ переработки нефти** | | | | | | | | | | | | | | |
| 25. Газ пиролиза | — | 0,5 | 31,0[3] | — | 0,8 | 14,0 | 41,0 | 12,0 | — | — | — | 0,2 | 11 322 | 0,996 |
| **VIII. Природный газ чисто газовых месторождений** | | | | | | | | | | | | | | |
| 26. Ухтинский | (2.6a) Следы | 0,3 | — | — | — | — | 88,0 | 1,9 | 0,2 | 0,3 | 0 | 9,3 | 7 946 | 0,789 |
| 27. Бугурусланский | 1,0 | 0,2 | — | — | — | — | 76,7 | 4,5 | 1,7 | 0,8 | 0,6 | 14,5 | 8 109 | 0,884 |
| 28. Курдюмский | Следы | — | — | — | — | — | 92,2 | 0,8 | — | 0,1 | 0 | 6,9 | 8 039 | 0,759 |
| 29. Елшанский (Саратовский) | • | 0,2 | — | — | — | — | 94,0 | 1,2 | 0,7 | 0,4 | 0,2 | 3,3 | 8 560 | 0,765 |
| 30. Мелитопольский | • | 0,2 | — | — | — | — | 97,9 | | 0,1 | | • | 1,8 | 8 391 | 0,729 |
| 31. Дашавский (Зап. Украина) | • | 0,1 | — | — | — | — | 97,9 | 0,5 | 0,2 | 0,1 | 0 | 1,2 | 8 523 | 0,730 |
| 32. Ставропольский | • | 0,1 | — | — | — | — | 98,0 | 0,4 | 0,2 | — | — | 1,3 | 8 489 | 0,730 |
| 33. Шебелинский | • | 0,3 | — | 0,2 | — | — | 89,9 | 3,1 | 0,9 | 0,4 | — | 5,2 | 8 472 | 0,790 |

Key: (a). Design characteristics of gaseous fuels. (b). Designation of gas. (c). Composition of gas in percentages by volume. (d). Unsaturated hydrocarbons. (e). Heat of combustion lowest of dry gas kcal/nm³. (f). Weight of normal cubic meter kg/nm³. I. Gas of blast furnaces. 1. Charcoal. 2. Coke. II. Generator went out. From the cake fuel/propellant. 3. Coke breeze. 4. Anthracite (donets. 5. Sulyutinskiy carbon/coal. 6. Bogoslovskiy carbon/coal. 7. Gas Donetskiy carbon/coal. 8. Lisichanskiy carbon/coal. 9. Cheremkhovskiy carbon/coal. 10. Chelyabinsk carbon/coal. 11. Moscow carbon/coal. 12. Peat machine-formed. 13. Hydro-peat. 14. Wood (chips). From the fine-grained fuel/propellant (0-6 mm) (gasification in suspended bed). 15. milled peat *.

FOOTNOTE *. Data according to the data of unit analyses. ENDFOOTNOTE.

16. Moscow carbon/coal *. III. Water gas [1].

FOOTNOTE [1]. For the large/coarse stations of water gas, equipped by gas generators in diameter of mine/shaft 3.6 m. ENDFOOTNOTE.

17. From coke. 18. From anthracite. IV. Gas of air blasting in obtaining of water gas. 19. From coke. 20. From anthracite. V. Gas of subterranean gasification. 21. From coal. 22. From Moscow

carbon/coal. VI. Gas of coke ovens. 23. Purified. 24. Not refined. VII. Gas of petroleum refining. 25. Gas of pyrolysis. VIII. The natural gas of purely gas fields. 26. Ukhtinskiy. (26a). Traces. 27. Buguruslanskiy. 28. Kurdyumskiy. (28a). Traces. 29. Yeshlanskiy (Saratov). 30. Melitopol'skiy. 31. Dashavskiy (W. Ukraine). 32. Stavropol. 33. Shebelinka.

FOOTNOTE [2]. Among other things of benzene $C_4H_6$ 0.8o/o.

[3]. Among other things $C_2H_4$ 17.0o/o, $C_4H_3$ 5.0o/o. ENDFOOTNOTE.

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Average/mean heat capacities of solid and liquid propellants, ash and combustible gases. RN-3-01.

Solid fuels.

The heat capacity cf the dry mass of fuel/propellant $c^c_{m\!\!\!/}$ kcal/kg hail is accepted: for the anthracite and the lean ccal - 0.22; for coals - 0.26; for the trcwn coal and the milling peat - 0.27; for the schists - 0.21.

Heat capacity of the working mass of the fuel/propellant

$$c^p_{m\!\!\!/}=\frac{W^p}{100}+c^c_{m\!\!\!/}\frac{100-W^p}{100}$$ kcal/kg deg.

Heat capacity of petroleum residue.

$$c_{m\!\!\!/}=0{,}415+0{,}0006t$$ kcal/kg deg.

The heat capacity of gaseous fuel, in reference to 1 nm³ of dry gas, is determined frcm the fcrmula

$$c_{z.ma} = c_{H_2}H_2 + c_{CO}CO + \\ + c_{CH_4}CH_4 + c_{CO_2}CO_2 + \\ + \ldots + 0{,}00124 c_{H_2O} d_{z.ma} \text{ kcal/nm}^3 \text{ deg.}$$

The heat capacities of combustible components of fuel/propellant are given in this RN, incombustible components - in Table 3-1.

Heat capacity of the ash of solid fuels (averaged date).

| t, °C | $c_{зл}$, ккал/кг·град (1) | t, °C | $c_{зл}$, ккал/кг·град (1) |
|---|---|---|---|
| 100 | 0,193 | 1 100 | 0,238 |
| 200 | 0,202 | 1 200 | 0,24 |
| 300 | 0,210 | 1 300 | 0,25 |
| 400 | 0,215 | 1 400 | 0,27 |
| 500 | 0,219 | 1 500 | 0,28 |
| 600 | 0,223 | 1 600 | 0,28 |
| 700 | 0,226 | 1 700 | 0,29 |
| 800 | 0,229 | 1 800 | 0,29 |
| 900 | 0,232 | 1 900 | 0,30 |
| 1 000 | 0,235 | 2 000 | 0,30 |

Notes: 1. The values of the heat capacity of ash at high temperatures are given with consideration of the heat of the transition from the solid to the liquid state.

2. The values of the heat capacity of ash at t>1600°C were determined approximately by the extrapolation of the experimental data.

Key: (1) kcal/kg deg.

Heat capacity of combustible gases.

| $t$, °C | (1) $c$, ккал/нм³ град | | |
|---|---|---|---|
| | CO | $H_2$ | $CH_4$ |
| 0 | 0,310 | 0,305 | 0,370 |
| 100 | 0,311 | 0,308 | 0,392 |
| 200 | 0,312 | 0,310 | 0,420 |
| 300 | 0,314 | 0,310 | 0,450 |
| 400 | 0,317 | 0,311 | 0,481 |
| 500 | 0,321 | 0,312 | 0,511 |
| 600 | 0,324 | 0,312 | 0,540 |
| 700 | 0,328 | 0,313 | 0,568 |
| 800 | 0,331 | 0,314 | 0,596 |
| 900 | 0,334 | 0,316 | 0,622 |
| 1 000 | 0,337 | 0,317 | 0,645 |

| $t$, °C | (1) $c$, ккал/нм³ град | | | | |
|---|---|---|---|---|---|
| | $H_2S$ | $C_2H_6$ | $C_3H_8$ | $C_4H_{10}$ | $C_5H_{12}$ |
| 0 | 0,360 | 0,528 | 0,728 | 0,986 | 1,225 |
| 100 | 0,366 | 0,596 | 0,838 | 1,124 | 1,394 |
| 200 | 0,373 | 0,663 | 0,947 | 1,255 | 1,556 |
| 300 | 0,381 | 0,727 | 1,044 | 1,379 | 1,704 |
| 400 | 0,390 | 0,790 | 1,137 | 1,497 | 1,849 |
| 500 | 0,399 | 0,849 | 1,217 | 1,598 | 1,972 |
| 600 | 0,408 | 0,902 | 1,297 | 1,699 | 2,098 |
| 700 | 0,417 | 0,952 | 1,367 | 1,788 | 2,205 |
| 800 | 0,426 | 0,999 | 1,430 | 1,865 | 2,299 |
| 900 | 0,434 | 1,042 | 1,488 | 1,938 | 2,386 |
| 1 000 | 0,442 | 1,082 | 1,543 | 2,007 | 2,471 |

Key: (1) s, kcal/nm³ deg.

Physical characteristics of petroleum residue. BN 3-02.

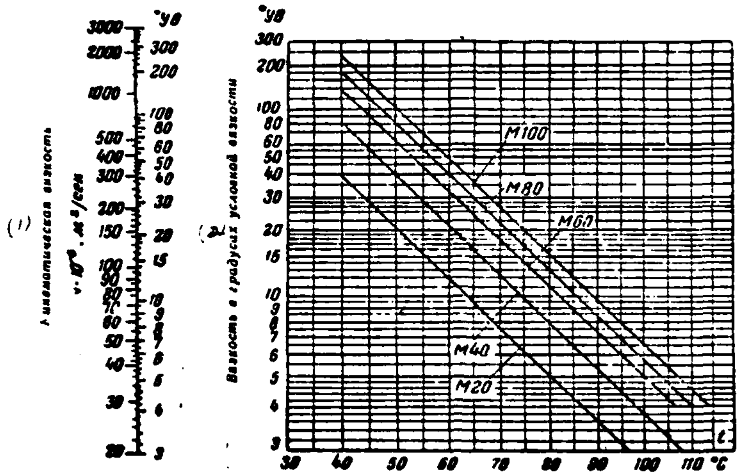
| (1) Физические свойства мазутов по ГОСТ 1501-52* | (2) Марка мазута | | | | |
|---|---|---|---|---|---|
| | 20 | 40 | 60 | 80 | 100 |
| (3) Вязкость при 80° С в градусах условной вязкости (от—до) | 2,5÷5,0 | 5,0÷8,0 | 8,0÷11,0 | 11,0÷13,0 | 13,0÷15,5 |
| (4) Температура вспышки не ниже, °С | 80 | 100 | 110 | 120 | 125 |
| (5) Температура застывания не выше, °С | +5 | +10 | +15 | +20 | +25 |

Key: (1). Physical properties of petroleum residue on GOST 1501-52*. (2). Brand/mark of petroleum residue. (3). Viscosity/ductility/toughness with 80°C in relative viscosity (from-to). (4). Flash point is not below, °C. (5). Solidification point is not above, °C.

Specific gravity/weight $\gamma^{20}_{4}$=920-1010 kg/m³; on the average $\gamma^{20}_{4}$~-990 of kg/m³.

New GOST 1501-57 provides for petroleum residue of brand 200, supplied to users only on the conduits/manifolds directly from the oil refinery. The physical properties of petroleum residue of brand 200 following: viscosity/ductility/toughness with 100°C in the degrees of relative viscosity 6.5-9.5, flash point is not lower than 140°C and solidification point is not higher than +36°C.

The dependence of the cceffıcients of the viscosity/ductility/toughness of petroleum residue on the temperature.




Key: (1). Kinematic viscosity $v \cdot 10^{-6} \cdot m^2 s$. (2). Viscosity/ductility/toughness in degrees of relative viscosity.

Coefficient of the thermal conductivity of petroleum residue.

| (1) Температура мазута | °C | 30 | 40 | 50 | 60 | 70 |
|---|---|---|---|---|---|---|
| (2) Мазут марки 20 . . . . . | (4) ккал/м час град | 0,103 | 0,102 | 0,101 | 0,099 | 0,098 |
| (3) Мазуты марок 40, 60, 80 и 100 . . . . . . . . . . . | ккал/м час град | 0,116 | 0,115 | 0,114 | 0,113 | 0,112 |

Key: (1). Temperature of petroleum residue. (2). Petroleum residue of brand 20. (3). Petroleum residue of brands 40, 60, 80 and 100. (4) kcal/m hour deg.

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Calculation of volumes and enthalpy of combustion products. RN 4-01.

The calculation of volumes and enthalpy of combustion products is recommended to take shape in the form of the following tables.

Volumes of gases, volume fractions of triatomic gases, concentration of ash.

| (1) Наименование величин | | $V^0 =$ | $V^0_{N_2} =$ | $V_{RO_2} =$ | $V^0_{H_2O} =$ | $A^p =$ | |
|---|---|---|---|---|---|---|---|
| | | (2) Наименования газоходов | | | | | |
| | | | | | | | |
| (3) Средние значения коэффициентов $\alpha$ в газоходах | — | | | | | | |
| $(\alpha - 1)V^0$ | (4) нм³/кг | | | | | | |
| $V_{H_2O} = V^0_{H_2O} + 0{,}0161(\alpha - 1)V^0$ | " | | | | | | |
| $V_г = V_{RO_2} + V^0_{N_2} + V_{H_2O} + (\alpha - 1)V^0$ | " | | | | | | |
| $r_{RO_2} = \frac{V_{RO_2}}{V_г}$ | — | | | | | | |
| $r_{H_2O} = \frac{V_{H_2O}}{V_г}$ | — | | | | | | |
| $r_n = r_{RO_2} + r_{H_2O}$ | — | | | | | | |
| $\mu = 10\frac{A^p a_{ун}}{V_г}$ | (5) г/нм³ | | | | | | |

Key: (1). Designation of values. (2). Designations of flues. (3). Average/mean values of coefficients $\alpha$ in flues. (4) nm³/kg. (5) g/nm³.

Enthalpy of combustion products. I $\vartheta$-table.

| θ, °C | $I_г^0$, ккал/кг (1) | $I_в^0$, ккал/кг (1) | $(c\theta)_{зл}^*$, ккал/кг град (2) | $I_{зл}^* = (c\theta)_{зл} a_{ун} \frac{A^р}{100}$, ккал/кг (1) | $I = I_г^0 + (\alpha - 1) I_в^0 + I_{зл}$, ккал/кг (1) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $\alpha_1$ | | $\alpha_2$ | | $\alpha_3$ | | $\alpha_4$ | |
| | | | | | $I$ | $\Delta I$ | $I$ | $\Delta I$ | $I$ | $\Delta I$ | $I$ | $\Delta I$ |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |

* The enthalpy of ash is considered only with $1000 \frac{a_{ун} A^р}{Q_н^р} > 6$.

Key: (1) kcal/kg. (2) kcal/kg deg.

The values of the theoretical volumes of air $V^0$, nitrogen $V_{N}^0$ and water vapors $V_{H_2O}^0$, volume of triatomic gases $V_{RO_2}$, enthalpy of the theoretical volume of flue gases $I_г^0$ and theoretically necessary volume of air $I_в^0$ for the fuels/propellants whose compositions are given in RN 2-01 and 2-02, are placed in RN 4-02, 4-03 and 4-05.

If calculation is conducted for the fuel/propellant of non-table composition, these values are calculated according to the formulas, led in chapter 4.

$a_{ун}$ - the share of the ash of fuel/propellant, taken away by gases, takes as the equal: for the pulverized-coal combustors with the dry slag removal - 0.9; for mine- mill heatings (besides the case of combusting the schists) - 0.85; the same during the combustion of schists - 0.7; for the liquid-bath furnaces - on RN 5-05; for the heatings with heated slag funnels -0.8-0.85; for the layer heatings - on RN 5-03 and 5-04.

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Volumes of air and combustion products of solid and liquid propellants with $\alpha$=1.

| (a) Район месторождения | (b) Наименование месторождения | (c) Марка и сорт | $V^0$ (d) нм³/кг | $V_{RO_2}$ (d) нм³/кг | $V^0_{N_2}$ (d) нм³/кг | $V^0_{H_2O}$ (d) нм³/кг | $V^0_г$ (d) нм³/кг |
|---|---|---|---|---|---|---|---|
| (e) Ископаемые угли | | | | | | | |
| 1. Донецкий бассейн | — | Д | 5,35 | 0,97 | 4,23 | 0,66 | 5,86 |
| 2. » » | — | Г | 6,53 | 1,18 | 5,17 | 0,66 | 7,01 |
| 3. » » | — | ПЖ | 6,53 | 1,19 | 5,17 | 0,60 | 6,96 |
| 4. » » | — | Т | 7,21 | 1,34 | 5,70 | 0,56 | 7,6 |
| 5. » » | — | 5a Полуантрацит | 7,20 | 1,36 | 5,69 | 0,50 | 7,55 |
| 6. » » | — | 6a АМ и АС | 7,21 | 1,44 | 5,70 | 0,34 | 7,48 |
| 7. » » | — | АРШ | 6,76 | 1,35 | 5,35 | 0,34 | 7,04 |
| 8. » » | — | АШ | 6,63 | 1,33 | 5,25 | 0,35 | 6,93 |
| 9. » » | — | ППМ | 4,15 | 0,75 | 3,28 | 0,49 | 4,52 |
| 10. » » | 11a — | 10a Шлам | 5,66 | 1,03 | 4,48 | 0,70 | 6,21 |
| 11. Кузнецкий бассейн | Анжеро-Судженское | ПС | 7,47 | 1,39 | 5,91 | 0,59 | 7,89 |
| 12. » » | Кемеровское 12a | К-ПС-СС | 6,64 | 1,22 | 5,25 | 0,64 | 7,11 |
| 13. » » | » | ПС-Т | 7,05 | 1,31 | 5,58 | 0,58 | 7,47 |
| 14. » » | Ленинское 14a | Д | 6,88 | 1,26 | 5,45 | 0,76 | 7,47 |
| 15. » » | » 16a | Г | 6,90 | 1,24 | 5,47 | 0,73 | 7,44 |
| 16. » » | Прокопьевско-Киселевское (Сталинуголь, Прокопьевскуголь, Кагановичуголь) | $СС_{23-26}$ | 7,26 | 1,33 | 5,75 | 0,70 | 7,78 |
| 17. » » | То же 17a | $СС_{18-25}$ | 7,41 | 1,37 | 5,87 | 0,63 | 7,87 |
| 18. » » | » » | $СС_{11-17}$ | 7,52 | 1,40 | 5,95 | 0,58 | 7,93 |
| 19. » » | Араличевское 19a | Т | 6,82 | 1,28 | 5,40 | 0,54 | 7,22 |
| 20. » » | — | ППС | 6,19 | 1,13 | 4,90 | 0,55 | 6,58 |
| 21. Карагандинский бассейн | — | ПЖ-ПС | 5,82 | 1,07 | 4,60 | 0,56 | 6,23 |
| 22. То же | — | Б | 4,09 | 0,79 | 3,23 | 0,69 | 4,71 |
| 23. Подмосковный бассейн | — | Б | 2,98 | 0,56 | 2,36 | 0,70 | 3,62 |
| 24. Печорский бассейн | — | ПЖ | 6,44 | 1,17 | 5,10 | 0,62 | 6,79 |
| 25. » » | 26a — | Д | 4,82 | 0,90 | 3,82 | 0,57 | 5,29 |
| 26. УССР Правобережье | Александрийское, Звенигородское, Коростышевское и др. | Б | 2,23 | 0,41 | 1,76 | 0,91 | 3,08 |
| 27. Западная Украина | 27a Золочевское (Тростянецкое) | Б | 2,92 | 0,55 | 2,31 | 0,76 | 3,62 |
| 28. » » | Коломыйское 28a | Б | 3,94 | 0,73 | 3,12 | 0,66 | 4,51 |
| 29. Закарпатская Украина | Мукачевское (Ильницкое) 29a | Б | 1,90 | 0,37 | 1,55 | 0,79 | 2,71 |
| 30. Башкирская АССР | Бабаевское (Ермолаевский разрез) 30a | Б | 2,78 | 0,50 | 2,20 | 0,97 | 3,67 |
| 31. Урал | Кизеловское 31a | Г | 5,52 | 0,99 | 4,37 | 0,57 | 5,93 |
| 32. » | » | Д | 5,52 | 1,00 | 4,37 | 0,58 | 5,95 |
| 33. » | » | ППМ | 4,38 | 0,77 | 3,47 | 0,53 | 4,77 |
| 34. » | Богословское 34a | Б | 3,27 | 0,64 | 2,59 | 0,67 | 3,90 |
| 35. » | Челябинское 35a | Б | 4,18 | 0,79 | 3,31 | 0,61 | 4,71 |
| 36. » | Буланашское 36a | Г | 5,99 | 1,09 | 4,74 | 0,66 | 6,49 |
| 37. » | Егоршинское 37a | А | 6,55 | 1,25 | 5,18 | 0,47 | 6,90 |
| 38. Грузинская ССР | Ткварчельское 38a | ПЖ | 4,67 | 0,84 | 3,69 | 0,57 | 5,10 |
| 39. » » | Ткибульское 39a | Г | 4,99 | 0,91 | 3,95 | 0,62 | 5,48 |
| 40. » » | Гелати 40a | Б | 3,45 | 0,65 | 2,73 | 0,47 | 3,85 |
| 41. » » | Ахалцихское 41a | Б | 2,86 | 0,53 | 2,26 | 0,56 | 3,34 |
| 42. Казахская ССР | Иртышское (Экибастуз) (42a) | СС | 4,51 | 0,83 | 3,57 | 0,50 | 4,90 |

Key: (a). region of deposit. (b). Designation of deposit. (c). Brand/mark and type. (d). $nm^3/kg$. (e). Coal. (f). Bituminous shale. 1. Donets basin. (5a). Carbonaceous coal. (6a). AE and AS. (10a). sludge. 11. Kuznetsk Basin. (11a). Anzhero-Sudzhenskiy. (12a.). Kemerovo. (14a). Leninist. (16a) Prokop'yevsko-Kiselevskiy (Stalinugol', Prokop'yevskugol', Kaganovichugol'). (17a). Then. (19a). Aralichevskiy. 21. Karaganda basin. 22. the same. 23. Moscow basin. 24. Pechora basin. 26. UkrSSR right bank. (26a). Alexandrine, Zvenigorodskiy, Korostyshevskiy, etc. 27. Western Ukraine. (27a). Zolochevskiy (Trostyanetskiy). (28a). Kolomyyskiy. 29. Transcarpathian Ukraine. (29a). Mukachevskiy (Il'nitskiy). 30. Bashkir ASSR. (30a). Babayevskiy (Yermolayevskiy section/cut). 31. Urals. (31a). Kizelovskiy. (34a). Theological. (35a). Chelyabinsk. (36a). Bulanashskiy. (37a). Yegorshinskiy. 38. Georgian SSR. (38a). Tkvarchel'skiy. (39a). Tkvibul'skiy. (40a). Gelati. (41a). Akhaltsikhskiy. 42. Kazakh SSR. (42a). Irtysh (Ekibastuz).

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Continuation RN 4-02.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 43. Казахская ССР | Ленгеровское 43a | Б | 4,41 | 0,84 | 3,49 | 0,70 | 5,03 |
| 44. Узбекская ССР | Ангрен 44a | Б | 4,03 | 0,79 | 3,18 | 0,72 | 4,69 |
| 45. Киргизская ССР | Кизыл-Кия 45a | Б | 4,50 | 0,87 | 3,56 | 0,70 | 5,13 |
| 46. . . | Сулюкта 46a | Б | 4,95 | 0,97 | 3,91 | 0,64 | 5,52 |
| 47. . . | Кок-Янгак 47a | Д | 5,35 | 1,00 | 4,23 | 0,66 | 5,89 |
| 48. . . | Ташкумыр 48a | Д | 5,96 | 1,11 | 4,71 | 0,68 | 6,50 |
| 49. Таджикская ССР | Шураб 49a | Б | 4,47 | 0,88 | 3,54 | 0,68 | 5,10 |
| 50. Красноярский край | Канское 50a | Б | 4,09 | 0,78 | 3,23 | 0,79 | 4,80 |
| 51. Хакасская А. О. | Минусинское 51a | Д | 7,28 | 1,27 | 5,77 | 0,81 | 7,85 |
| 52. Иркутская обл. | Черемховское 52a | Д | 5,17 | 0,94 | 4,09 | 0,67 | 5,70 |
| 53. Бурят-Монгольская АССР | Гусино-Озерское 53a | Б | 4,70 | 0,89 | 3,72 | 0,69 | 5,30 |
| 54. Читинская обл. | Тарбагатайское 54a | Б | 4,71 | 0,88 | 3,72 | 0,73 | 5,33 |
| 55. . . | Черновское 55a | Б | 4,43 | 0,84 | 3,51 | 0,82 | 5,17 |
| 56. . . | Арабагарское 56a | Б | 4,15 | 0,80 | 3,28 | 0,70 | 4,78 |
| 57. . . | Букачачинское 57a | Г | 6,74 | 1,23 | 5,33 | 0,70 | 7,26 |
| 58. . . | . | Д | 6,18 | 1,14 | 4,89 | 0,73 | 6,76 |
| 59. Хабаровский край | Райчихинское 59a | Б | 3,56 | 0,71 | 2,81 | 0,77 | 4,29 |
| 60. . . | Кивдинское 60a | Б | 3,74 | 0,73 | 2,96 | 0,75 | 4,44 |
| 61. . . | Ургальское (Бурея) 61a | Г | 5,28 | 0,95 | 4,18 | 0,57 | 5,70 |
| 62. Приморский край | Сучанское 62a | Г | 5,60 | 1,02 | 4,43 | 0,56 | 6,01 |
| 63. . . | . | ПЖ | 6,29 | 1,16 | 4,98 | 0,58 | 6,72 |
| 64. . . | . | Т | 6,30 | 1,19 | 4,98 | 0,49 | 6,66 |
| 65. . . | Артемовское 65a | Б | 3,57 | 0,66 | 2,83 | 0,73 | 4,22 |
| 66. . . | Тавричанское 66a | Б | 4,79 | 0,89 | 3,79 | 0,64 | 5,32 |
| 67. . . | Подгородненское 67a | Т | 5,02 | 0,93 | 3,97 | 0,43 | 5,33 |
| 68. . . | Ворошиловское 68a | СС | 4,75 | 0,87 | 3,76 | 0,47 | 5,10 |
| 69. . . | Липовецкое 69a | Д | 4,98 | 0,91 | 3,94 | 0,61 | 5,46 |
| г) Горючие сланцы | | | | | | | |
| 70. Эстонская ССР | — | — | 2,99 | 0,55* | 2,36 | 0,59 | 3,50 |
| 71. Ленинградская обл. | Гдовское 71a | — | 2,32 | 0,45* | 1,83 | 0,50 | 2,78 |
| 72. Куйбышевская обл. | Кашпирское 72a | — | 1,80 | 0,35* | 1,42 | 0,48 | 2,25 |
| 73. Саратовская обл. | Савельевское 73a | — | 1,70 | 0,33* | 1,35 | 0,48 | 2,16 |
| 74. . . | Озинское 74a | — | 1,73 | 0,32* | 1,37 | 0,50 | 2,19 |
| 75. Торф | — | 75a Кусковой | 3,01 | 0,58 | 2,39 | 0,99 | 3,87 |
| 76. . | — | 76a Фрезерный | 2,51 | 0,48 | 1,99 | 0,96 | 3,43 |
| 77. Дрова | — | — | 2,81 | 0,57 | 2,23 | 0,95 | 3,75 |
| 78. Коксовая мелочь | — | — | 5,91 | 1,18 | 4,68 | 0,50 | 6,36 |
| 79. Мазут | — | 79a Малосернистый | 10,28 | 1,60 | 8,12 | 1,34 | 11,06 |
| 80. . | — | 80a Высокосернистый | 10,15 | 1,58 | 8,02 | 1,32 | 10,92 |

* During calculaticn $v_{RO}$, tor the schists the coefficient of the expansion of carbonates k is accepted equal tc unit.

Key: 43. Kazakh SSR. (43a). Lengercvskiy. 44. Uzbek SSR. (44a). Angren. 45. Kirghiz SSR. (45a). Kyzyl-Kiya. (46a). Sulyukta. (47a). Kok-Yangak. (48a). Tashkuayr. 49. Tadzhik SSR. (49a). Shurab. 50. Krasnoyarsk edge. (50a). Kanskiy. 51. A. O. Khakasskaya. (51a). Minusinsk. 52. Irkutsk Obl. (52a). Cheremkhcvskiy. 53. Buryat-Mongolian ASSR. (53a). Gusino-Ozerskiy. 54. Chita Obl. (54a). Tarbagatayskiy. (55a). Chernovskiy. (56a) Aratagarskiy. (57a). Bukachachinskiy. 59. Khabarcvsk edge. (59a). Raychikhinskiy. (60a). Kivdinskiy. (61a). Urgal'skiy (Bureya). 62. Seaside edge. (62a). Suchanskiy. (65a). Artemcvskiy. (66a). Tavrichanskiy. (67a). Podgorcdnenskiy. (68a). Voroshilovskiy. (69a). Lipovetskiy. (f). Fuel schists. (70). Estonia. 71. Leningrad Obl. (71a). Gdcvskiy. 72. Kuybyshev Obl. (72a). Kashpirskiy. 73. Saratcv Obl. (73a). Savel'yevskiy. (74a). Ozinskiy. 75. Peat. (75a). Cake. (76a). Milling. 77. Firewood. 78. Coke breeze. 79. Petroleum residue. (79a). Lcw-sulfur. (80a). High-sulphur.

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Volumes of air and combustion products of gaseous fuels with $\alpha=1$. RN 4-03.

| (a) Наименование газа | (b) Все величины подсчитаны на 1 нм³ сухого газа | | | | |
|---|---|---|---|---|---|
| | $V^0$ | $V_{RO_2}$ | $V^0_{N_2}$ | $V^{0*}_{H_2O}$ | $V^0_г$ |
| | (c) нм³/нм³ | (c) нм³/нм³ | (c) нм³/нм³ | (c) нм³/нм³ | (c) нм³/нм³ |
| 1 | 2 | 3 | 4 | 5 | 6 |
| I. Газ доменных печей | | | | | |
| 1. Древесноугольных | 0,99 | 0,41 | 1,30 | 0,13 | 1,84 |
| 2. Коксовых | 0,78 | 0,39 | 1,20 | 0,05 | 1,64 |
| II. Генераторный газ. Из кускового топлива | | | | | |
| 3. Коксовая мелочь | 1,06 | 0,34 | 1,36 | 0,16 | 1,86 |
| 4. Антрацит донецкий | 1,03 | 0,34 | 1,34 | 0,16 | 1,84 |
| 5. Сулюктинский уголь | 1,13 | 0,35 | 1,39 | 0,18 | 1,92 |
| 6. Богословский „ | 1,14 | 0,35 | 1,42 | 0,20 | 1,97 |
| 7. Газовый донецкий уголь | 1,23 | 0,35 | 1,49 | 0,21 | 2,05 |
| 8. Лисичанский уголь | 1,30 | 0,36 | 1,52 | 0,24 | 2,12 |
| 9. Черемховский „ | 1,28 | 0,36 | 1,50 | 0,24 | 2,10 |
| 10. Челябинский „ | 1,25 | 0,38 | 1,48 | 0,20 | 2,06 |
| 11. Подмосковный „ | 1,26 | 0,36 | 1,50 | 0,22 | 2,08 |
| 12. Торф машиноформовочный | 1,37 | 0,40 | 1,54 | 0,24 | 2,18 |
| 13. Гидроторф | 1,31 | 0,39 | 1,49 | 0,23 | 2,11 |
| 14. Древесина (щепа) | 1,36 | 0,39 | 1,54 | 0,23 | 2,16 |
| 14a Из мелкозернистого топлива (0÷6 мм) (газификация во взвешенном слое) | | | | | |
| 15. Фрезерный торф | 1,01 | 0,33 | 1,36 | 0,18 | 1,87 |
| 16. Подмосковный уголь | 0,87 | 0,31 | 1,31 | 0,12 | 1,74 |
| III. Водяной газ | | | | | |
| 17. Из кокса | 2,13 | 0,44 | 1,74 | 0,55 | 2,73 |
| 18. „ антрацита | 2,13 | 0,45 | 1,75 | 0,53 | 2,73 |
| IV. Газ воздушной продувки при получении водяного газа | | | | | |
| 19. Из кокса | 0,15 | 0,23 | 0,88 | 0,02 | 1,13 |
| 20. „ антрацита | 0,28 | 0,24 | 0,96 | 0,03 | 1,23 |
| V. Газ подземной газификации | | | | | |
| 21. Из каменного угля | 0,91 | 0,31 | 1,30 | 0,17 | 1,78 |
| 22. „ подмосковного угля | 0,80 | 0,22 | 1,27 | 0,20 | 1,69 |
| VI. Газ коксовых печей | | | | | |
| 23. Очищенный | 3,93 | 0,36 | 3,18 | 1,13 | 4,67 |
| 24. Неочищенный | 4,19 | 0,40 | 3,39 | 1,15 | 4,94 |
| VII. Газ переработки нефти | | | | | |
| 25. Газ пиролиза | 12,05 | 1,47 | 9,52 | 2,32 | 13,31 |
| VIII. Природный газ чисто газовых месторождений | | | | | |
| 26. Ухтинский | 8,83 | 0,94 | 7,07 | 1,98 | 9,99 |
| 27. Бугурусланский | 9,01 | 0,98 | 7,27 | 1,97 | 10,22 |
| 28. Курдюмский | 8,94 | 0,94 | 7,13 | 2,02 | 10,09 |
| 29. Елшанский (Саратовский) | 9,51 | 1,01 | 7,54 | 2,13 | 10,68 |
| 30. Мелитопольский | 9,34 | 0,98 | 7,40 | 2,11 | 10,49 |
| 31. Дашавский (Западная Украина) | 9,48 | 1,00 | 7,50 | 2,14 | 10,64 |

* The volume of water vapors is calculated without taking into account the moisture, which is contained in the gaseous fuel.

Key: (a). Designation of gas. (b). All values are calculated on 1 $Km^3$ of dry gas. (c). $Km^3/Km^3$. I. Gas of blast furnaces. 1. Charccal. 2. Coke. II. Generator gas. Frcm the cake fuel/propellant. 3. Ccke breeze. 4. Anthracite dcnets. 5. Sulyutinskiy carbcn/coal. 6. Bogoslovskiy carbon/coal. 7. Gas Dcnetskiy carbcn/ccal. 8. Lisichanskiy carbon/coal. 9. Cheremkhovskiy ccal. 10. Chelyabinsk carbon/coal. 11. Moscow carbcn/ccal. 12. Peat machine-formed. 13. Hydro-peat. 14. Wood (chips). (14a). From the fine-grained fuel/propellant (0-6 mm) (gasification in suspended bed). 15. Milling peat. 16. Moscow carbon/coal. III. Water gas. 17. From coke. 18. From anthracite. IV. Gas of air blasting in obtaining of water gas. 19. From coke. 20. From anthracite. V. Gas of subterranean gasification. 21. From coal. 22. Frcm Moscow carbon/coal. VI. Gas of coke cvens. 23. Purified. 24. Not refined. VII. Gas cf petroleum refining. 25. Gas of pyrolysis. VIII. The natural gas cf purely gas fields. 26. Ukhtinskiy. 27. Buguruslanskiy. 28. Kurdyumskiy. 29. Yelshanskiy (Saratov). 30. Melitopcl'skiy. 31. Dashavskiy (Western Ukraine).

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Enthalpy 1 nm³ of air and gases and 1 kg of ash. BN 4-04.

| $\vartheta$ | $(c\vartheta)_{CO_2}$ | $(c\vartheta)_{N_2}$ | $(c\vartheta)_{O_2}$ | $(c\vartheta)_{H_2O}$ | $(c\vartheta)_{в}$ | $(c\vartheta)_{зл}$ |
|---|---|---|---|---|---|---|
| °C | (1) ккал/нм³ | (1) ккал/нм³ | (1) ккал/нм³ | (1) ккал/нм³ | (1) ккал/нм³ | (2) ккал/кг |
| 100 | 40,6 | 31,0 | 31,5 | 36,0 | 31,6 | 19,3 |
| 200 | 85,4 | 62,1 | 63,8 | 72,7 | 63,6 | 40,4 |
| 300 | 133,5 | 93,6 | 97,2 | 110,5 | 96,2 | 63,0 |
| 400 | 184,4 | 125,8 | 131,6 | 149,6 | 129,4 | 86,0 |
| 500 | 238 | 158,6 | 167,0 | 189,8 | 163,4 | 109,5 |
| 600 | 292 | 192,0 | 203 | 231 | 198,2 | 133,8 |
| 700 | 349 | 226 | 240 | 274 | 234 | 158,2 |
| 800 | 407 | 261 | 277 | 319 | 270 | 183,2 |
| 900 | 466 | 297 | 315 | 364 | 306 | 209 |
| 1 000 | 526 | 333 | 353 | 412 | 343 | 235 |
| 1 100 | 587 | 369 | 391 | 460 | 381 | 262 |
| 1 200 | 649 | 405 | 430 | 509 | 419 | 288 |
| 1 300 | 711 | 442 | 469 | 560 | 457 | 325 |
| 1 400 | 774 | 480 | 508 | 611 | 496 | 378 |
| 1 500 | 837 | 517 | 548 | 664 | 535 | 420 |
| 1 600 | 900 | 555 | 588 | 717 | 574 | 448 |
| 1 700 | 964 | 593 | 628 | 771 | 613 | 493 |
| 1 800 | 1 028 | 631 | 668 | 826 | 652 | 522 |
| 1 900 | 1 092 | 670 | 709 | 881 | 692 | 570 |
| 2 000 | 1 157 | 708 | 750 | 938 | 732 | 600 |
| 2 100 | 1 222 | 747 | 790 | 994 | 772 | — |
| 2 200 | 1 287 | 786 | 832 | 1 061 | 812 | — |

Key: (1) kcal/nm³. (2) kcal/kg.

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(a) ТЕПЛОСОДЕРЖАНИЯ ВОЗДУХА И ПРОДУКТОВ СГОРАНИЯ НА 1 кг ТВЕРДЫХ И ЖИДКИХ ТОПЛИВ ПРИ $\alpha = 1$ | РН 4-05

| (b) Район месторождения | (c) Наименование месторождения | (d) Марка и сорт | | (e) Температура, °C | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 | 900 | 1 000 | 1 100 |
| (f) Ископаемые угли | | | | | | | | | | | | | | |
| 1. Донецкий бассейн | — | Д | $I_в^0$ | 194 | 394 | 599 | 810 | 1 027 | 1 250 | 1 478 | 1 711 | 1 948 | 2 190 | 2 435 |
| | | | $I_г^0$ | 169 | 340 | 514 | 692 | 874 | 1 060 | 1 249 | 1 442 | 1 637 | 1 835 | 2 036 |
| 2. » » | — | Г | $I_в^0$ | 232 | 470 | 714 | 966 | 1 225 | 1 491 | 1 763 | 2 041 | 2 323 | 2 612 | 2 904 |
| | | | $I_г^0$ | 207 | 416 | 628 | 845 | 1 067 | 1 294 | 1 526 | 1 761 | 2 000 | 2 242 | 2 488 |
| 3. » » | — | ПЖ | $I_в^0$ | 230 | 467 | 709 | 959 | 1 217 | 1 480 | 1 751 | 2 026 | 2 307 | 2 593 | 2 883 |
| | | | $I_г^0$ | 207 | 416 | 628 | 845 | 1 067 | 1 295 | 1 526 | 1 762 | 2 001 | 2 242 | 2 488 |
| 4. » » | — | Т | $I_в^0$ | 251 | 509 | 774 | 1 047 | 1 327 | 1 615 | 1 910 | 2 211 | 2 517 | 2 829 | 3 145 |
| | | | $I_г^0$ | 228 | 458 | 693 | 932 | 1 177 | 1 428 | 1 684 | 1 943 | 2 207 | 2 474 | 2 745 |
| 5. » » | — | 5a Полуантрацит | $I_в^0$ | 250 | 506 | 770 | 1 041 | 1 321 | 1 607 | 1 900 | 2 200 | 2 504 | 2 815 | 3 129 |
| | | | $I_г^0$ | 228 | 458 | 692 | 931 | 1 176 | 1 426 | 1 681 | 1 940 | 2 204 | 2 470 | 2 741 |
| 6. » » | — | (6a) АМ и АС | $I_в^0$ | 247 | 502 | 763 | 1 033 | 1 310 | 1 595 | 1 886 | 2 183 | 2 485 | 2 793 | 3 105 |
| | | | $I_г^0$ | 228 | 458 | 693 | 932 | 1 178 | 1 428 | 1 684 | 1 943 | 2 207 | 2 474 | 2 745 |
| 7. » » | — | АРШ | $I_в^0$ | 233 | 472 | 718 | 972 | 1 233 | 1 500 | 1 775 | 2 054 | 2 339 | 2 627 | 2 922 |
| | | | $I_г^0$ | 214 | 430 | 650 | 875 | 1 105 | 1 340 | 1 580 | 1 824 | 2 071 | 2 321 | 2 576 |
| 8. » » | — | АШ | $I_в^0$ | 229 | 465 | 707 | 957 | 1 213 | 1 477 | 1 747 | 2 022 | 2 302 | 2 587 | 2 875 |
| | | | $I_г^0$ | 210 | 422 | 638 | 858 | 1 084 | 1 315 | 1 550 | 1 789 | 2 032 | 2 278 | 2 527 |
| 9. » » | — | ППМ | $I_в^0$ | 150 | 304 | 462 | 624 | 792 | 963 | 1 140 | 1 319 | 1 502 | 1 688 | 1 877 |
| | | | $I_г^0$ | 131 | 264 | 399 | 536 | 677 | 821 | 969 | 1 118 | 1 270 | 1 423 | 1 579 |
| 10. » » | — | (10a) Шлам | $I_в^0$ | 206 | 417 | 634 | 857 | 1 087 | 1 323 | 1 565 | 1 812 | 2 063 | 2 319 | 2 579 |
| | | | $I_г^0$ | 179 | 360 | 544 | 732 | 925 | 1 121 | 1 322 | 1 526 | 1 733 | 1 942 | 2 155 |
| 11. Кузнецкий бассейн | (11a) Анжеро-Судженское | ПС | $I_в^0$ | 261 | 529 | 804 | 1 087 | 1 379 | 1 677 | 1 984 | 2 296 | 2 614 | 2 938 | 3 266 |
| | | | $I_г^0$ | 236 | 475 | 719 | 967 | 1 221 | 1 480 | 1 746 | 2 015 | 2 288 | 2 565 | 2 846 |

Key: (a). Enthalpy of air and combustion products on 1 kg of solid and liquid propellants with $\alpha$=1. EN 4-05. (b). Region of deposit. (c). Designation of deposit. (d). Brand/mark and type. (e). Temperature, °C. (f). Coal. 1. Donets basin. (5a). Carbonaceous coal. (6a). AM and AS. (10a). Slime. 11. Kuznetsk Basin. (11a). Anzhero-Sudzhenskiy.

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(f) Ископаемые угли

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Донецкий бассейн | — | Д | $I_г^0$ | 2 683 | 2 933 | 3 187 | 3 441 | 3 698 | 3 957 | 4 217 | 4 479 | 4 741 | 5 003 | 5 268 |
| | | | $I_в^0$ | 2 239 | 2 444 | 2 651 | 2 859 | 3 068 | 3 278 | 3 488 | 3 701 | 3 914 | 4 129 | 4 344 |
| 2. " " | — | Г | $I_г^0$ | 3 199 | 3 496 | 3 799 | 4 101 | 4 407 | 4 715 | 5 024 | 5 335 | 5 647 | 5 960 | 6 273 |
| | | | $I_в^0$ | 2 735 | 2 986 | 3 239 | 3 493 | 3 748 | 4 005 | 4 262 | 4 522 | 4 782 | 5 044 | 5 306 |
| 3. " " | — | ПЖ | $I_г^0$ | 3 175 | 3 470 | 3 771 | 4 071 | 4 374 | 4 679 | 4 986 | 5 295 | 5 604 | 5 913 | 6 225 |
| | | | $I_в^0$ | 2 736 | 2 987 | 3 239 | 3 493 | 3 749 | 4 005 | 4 262 | 4 523 | 4 783 | 5 045 | 5 307 |
| 4. " " | — | Т | $I_г^0$ | 3 464 | 3 786 | 4 113 | 4 440 | 4 770 | 5 103 | 5 436 | 5 773 | 6 110 | 6 446 | 6 785 |
| | | | $I_в^0$ | 3 017 | 3 294 | 3 573 | 3 853 | 4 135 | 4 418 | 4 701 | 4 989 | 5 276 | 5 565 | 5 854 |
| 5. " " | — | (5a) Полуантрацит | $I_г^0$ | 3 446 | 3 766 | 4 093 | 4 417 | 4 745 | 5 075 | 5 407 | 5 742 | 6 077 | 6 411 | 6 748 |
| | | | $I_в^0$ | 3 013 | 3 290 | 3 568 | 3 847 | 4 129 | 4 412 | 4 695 | 4 982 | 5 268 | 5 557 | 5 846 |
| 6. " " | — | (6a) АМ и АС | $I_г^0$ | 3 419 | 3 736 | 4 059 | 4 381 | 4 706 | 5 034 | 5 362 | 5 693 | 6 024 | 6 355 | 6 688 |
| | | | $I_в^0$ | 3 018 | 3 295 | 3 573 | 3 853 | 4 136 | 4 419 | 4 702 | 4 989 | 5 276 | 5 566 | 5 855 |
| 7. " " | — | АРШ | $I_г^0$ | 3 218 | 3 516 | 3 820 | 4 123 | 4 429 | 4 737 | 5 046 | 5 358 | 5 670 | 5 931 | 6 295 |
| | | | $I_в^0$ | 2 832 | 3 092 | 3 353 | 3 616 | 3 881 | 4 147 | 4 412 | 4 682 | 4 951 | 5 223 | 5 494 |
| 8. " " | — | АШ | $I_г^0$ | 3 167 | 3 461 | 3 760 | 4 058 | 4 359 | 4 662 | 4 967 | 5 274 | 5 531 | 5 888 | 6 196 |
| | | | $I_в^0$ | 2 778 | 3 033 | 3 290 | 3 548 | 3 807 | 4 069 | 4 329 | 4 593 | 4 857 | 5 124 | 5 390 |
| 9. " " | — | ППМ | $I_г^0$ | 2 068 | 2 261 | 2 457 | 2 655 | 2 850 | 3 050 | 3 250 | 3 452 | 3 654 | 3 857 | 4 060 |
| | | | $I_в^0$ | 1 736 | 1 895 | 2 056 | 2 217 | 2 379 | 2 542 | 2 705 | 2 870 | 3 035 | 3 201 | 3 368 |
| 10. " " | — | (10a) Шлам | $I_г^0$ | 2 841 | 3 105 | 3 375 | 3 644 | 3 915 | 4 190 | 4 465 | 4 743 | 5 021 | 5 299 | 5 578 |
| | | | $I_в^0$ | 2 370 | 2 587 | 2 806 | 3 026 | 3 247 | 3 469 | 3 692 | 3 917 | 4 143 | 4 370 | 4 597 |
| 11. Кузнецкий бассейн | (11a) Анжеро-Судженское | ПС | $I_г^0$ | 3 598 | 3 932 | 4 272 | 4 611 | 4 954 | 5 300 | 5 648 | 5 996 | 6 346 | 6 696 | 7 048 |
| | | | $I_в^0$ | 3 128 | 3 415 | 3 704 | 3 995 | 4 287 | 4 581 | 4 874 | 5 172 | 5 470 | 5 770 | 6 069 |

Key: (f). Coal. 1. Donets basin. (5a). Carbonaceous coal. (6a). and. (10a). slime. 11. Kuznetsk Basin. (11a). Anzhero-Sudzhenskiy.

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Continuation RN 4-05.

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12. Кузнецкий бассейн | Кемеровское 12a | К-ПС-СС | $I_г^0$ | 235 | 477 | 725 | 980 | 1 243 | 1 512 | 1 789 | 2 071 | 2 357 | 2 649 | 2 946 |
| | | | $I_в^0$ | 210 | 422 | 638 | 859 | 1 084 | 1 315 | 1 550 | 1 789 | 2 032 | 2 278 | 2 528 |
| 13. » » | » | ПС-Т | $I_г^0$ | 247 | 501 | 761 | 1 030 | 1 306 | 1 539 | 1 879 | 2 175 | 2 476 | 2 784 | 3 095 |
| | | | $I_в^0$ | 223 | 449 | 678 | 912 | 1 152 | 1 397 | 1 647 | 1 901 | 2 159 | 2 420 | 2 685 |
| 14. » » | Ленинское 14a | Д | $I_г^0$ | 247 | 501 | 761 | 1 030 | 1 305 | 1 539 | 1 879 | 2 175 | 2 477 | 2 784 | 3 096 |
| | | | $I_в^0$ | 218 | 438 | 661 | 890 | 1 124 | 1 363 | 1 607 | 1 855 | 2 106 | 2 361 | 2 620 |
| 15. » » | » | Г | $I_г^0$ | 246 | 499 | 758 | 1 025 | 1 300 | 1 581 | 1 870 | 2 165 | 2 465 | 2 770 | 3 080 |
| | | | $I_в^0$ | 218 | 439 | 663 | 892 | 1 127 | 1 366 | 1 611 | 1 859 | 2 112 | 2 367 | 2 627 |
| 16. » » | 16a Прокопьевско-Киселевское (Сталинуголь, Прокопьевскуголь, Кагановичуголь) | СС$_{35-36}$ | $I_г^0$ | 257 | 522 | 793 | 1 073 | 1 361 | 1 656 | 1 959 | 2 267 | 2 581 | 2 901 | 3 226 |
| | | | $I_в^0$ | 230 | 462 | 699 | 940 | 1 187 | 1 439 | 1 697 | 1 958 | 2 224 | 2 493 | 2 766 |
| 17. » » | То же 17a | СС$_{18-25}$ | $I_г^0$ | 260 | 527 | 801 | 1 084 | 1 374 | 1 672 | 1 978 | 2 289 | 2 606 | 2 929 | 3 257 |
| | | | $I_в^0$ | 234 | 471 | 713 | 959 | 1 211 | 1 468 | 1 731 | 1 998 | 2 269 | 2 544 | 2 822 |
| 18. » » | » » | СС$_{11-17}$ | $I_г^0$ | 262 | 532 | 808 | 1 093 | 1 387 | 1 687 | 1 995 | 2 310 | 2 629 | 2 955 | 3 285 |
| | | | $I_в^0$ | 238 | 478 | 723 | 973 | 1 229 | 1 490 | 1 757 | 2 027 | 2 303 | 2 581 | 2 864 |
| 19. » » | Араличевское 19a | Т | $I_г^0$ | 239 | 484 | 736 | 996 | 1 263 | 1 536 | 1 817 | 2 103 | 2 391 | 2 691 | 2 992 |
| | | | $I_в^0$ | 216 | 434 | 656 | 883 | 1 115 | 1 352 | 1 594 | 1 840 | 2 089 | 2 342 | 2 600 |
| 20. » » | — | ППС | $I_г^0$ | 217 | 441 | 670 | 907 | 1 150 | 1 399 | 1 655 | 1 915 | 2 180 | 2 450 | 2 724 |
| | | | $I_в^0$ | 196 | 394 | 595 | 800 | 1 011 | 1 226 | 1 445 | 1 668 | 1 894 | 2 123 | 2 356 |
| 21. Карагандинский бассейн | — | ПЖ-ПС | $I_г^0$ | 206 | 418 | 636 | 860 | 1 091 | 1 327 | 1 570 | 1 817 | 2 068 | 2 325 | 2 585 |
| | | | $I_в^0$ | 184 | 370 | 560 | 753 | 951 | 1 153 | 1 359 | 1 569 | 1 782 | 1 997 | 2 216 |
| 22. То же | — | Б | $I_г^0$ | 157 | 318 | 484 | 654 | 830 | 1 010 | 1 195 | 1 384 | 1 576 | 1 772 | 1 971 |
| | | | $I_в^0$ | 129 | 260 | 393 | 529 | 668 | 810 | 955 | 1 102 | 1 251 | 1 402 | 1 556 |
| 23. Подмосковный бассейн | — | Б | $I_г^0$ | 121 | 246 | 373 | 505 | 641 | 780 | 923 | 1 069 | 1 217 | 1 369 | 1 523 |
| | | | $I_в^0$ | 94 | 189 | 286 | 385 | 486 | 590 | 695 | 803 | 911 | 1 022 | 1 134 |

Key: 12. The Kuznetsk Basin. (12a). Kemerovo. (14a). Leninist. (16a). Prokop'yevskiy-Kiselevskiy (Stalinugol', Prokop'yevskugol', Kaganovichugol'). (17a). the same (19a). Aralichevskiy. 21. Karaganda basin. 22. the same 23. Moscow basin.

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12. Кузнецкий бассейн | Кемеровское 12a | К-ПС-СС | $I_z^0$ | 3 245 | 3 547 | 3 854 | 4 161 | 4 470 | 4 783 | 5 096 | 5 412 | 5 728 | 6 051 | 6 369 |
| | | | $I_e^0$ | 2 779 | 3 034 | 3 290 | 3 548 | 3 808 | 4 068 | 4 329 | 4 594 | 4 858 | 5 125 | 5 391 |
| 13. » » | » | ПС-Т | $I_z^0$ | 3 409 | 3 725 | 4 047 | 4 369 | 4 694 | 5 022 | 5 351 | 5 682 | 6 013 | 6 345 | 6 679 |
| | | | $I_e^0$ | 2 952 | 3 223 | 3 496 | 3 770 | 4 046 | 4 322 | 4 600 | 4 881 | 5 161 | 5 445 | 5 727 |
| 14. » » | Ленинское 14a | Д | $I_z^0$ | 3 410 | 3 728 | 4 051 | 4 374 | 4 699 | 5 028 | 5 359 | 5 691 | 6 024 | 6 357 | 6 692 |
| | | | $I_e^0$ | 2 880 | 3 144 | 3 410 | 3 678 | 3 947 | 4 217 | 4 487 | 4 761 | 5 035 | 5 312 | 5 587 |
| 15. » » | » | Г | $I_z^0$ | 3 393 | 3 709 | 4 030 | 4 350 | 4 675 | 5 002 | 5 330 | 5 661 | 5 992 | 6 324 | 6 657 |
| | | | $I_e^0$ | 2 888 | 3 153 | 3 419 | 3 687 | 3 957 | 4 228 | 4 499 | 4 774 | 5 049 | 5 326 | 5 602 |
| 16. » » 16a | Прокопьевско-Киселевское (Сталинуголь, Прокопьевскуголь, Кагановичуголь) | $CC_{26-35}$ | $I_z^0$ | 3 553 | 3 883 | 4 220 | 4 556 | 4 895 | 5 237 | 5 580 | 5 926 | 6 272 | 6 619 | 6 967 |
| | | | $I_e^0$ | 3 041 | 3 320 | 3 601 | 3 883 | 4 168 | 4 453 | 4 739 | 5 028 | 5 317 | 5 609 | 5 900 |
| 17. » » 17a | То же | $CC_{18-25}$ | $I_z^0$ | 3 587 | 3 921 | 4 260 | 4 599 | 4 940 | 5 285 | 5 631 | 5 980 | 6 329 | 6 679 | 7 030 |
| | | | $I_e^0$ | 3 103 | 3 387 | 3 674 | 3 932 | 4 252 | 4 543 | 4 834 | 5 130 | 5 425 | 5 724 | 6 019 |
| 18. » » | » » | $CC_{11-17}$ | $I_z^0$ | 3 619 | 3 955 | 4 297 | 4 638 | 4 983 | 5 331 | 5 679 | 6 031 | 6 383 | 6 733 | 7 088 |
| | | | $I_e^0$ | 3 149 | 3 437 | 3 728 | 4 023 | 4 315 | 4 610 | 4 906 | 5 205 | 5 505 | 5 808 | 6 108 |
| 19. » » | 19a Араличевское | Т | $I_z^0$ | 3 296 | 3 602 | 3 913 | 4 225 | 4 538 | 4 855 | 5 173 | 5 493 | 5 814 | 6 134 | 6 457 |
| | | | $I_e^0$ | 2 857 | 3 119 | 3 383 | 3 648 | 3 915 | 4 183 | 4 451 | 4 723 | 4 995 | 5 271 | 5 543 |
| 20. » » | — | ППС | $I_z^0$ | 3 000 | 3 279 | 3 563 | 3 846 | 4 132 | 4 421 | 4 710 | 5 002 | 5 294 | 5 588 | 5 882 |
| | | | $I_e^0$ | 2 590 | 2 828 | 3 067 | 3 308 | 3 550 | 3 793 | 4 036 | 4 282 | 4 529 | 4 779 | 5 025 |
| 21. Карагандинский бассейн | — | ПЖ-ПС | $I_z^0$ | 2 848 | 3 112 | 3 382 | 3 651 | 3 923 | 4 197 | 4 472 | 4 749 | 5 027 | 5 304 | 5 584 |
| | | | $I_e^0$ | 2 436 | 2 660 | 2 885 | 3 111 | 3 339 | 3 567 | 3 796 | 4 027 | 4 259 | 4 494 | 4 726 |
| 22. То же | — | Б | $I_z^0$ | 2 172 | 2 375 | 2 581 | 2 787 | 2 996 | 3 207 | 3 419 | 3 633 | 3 846 | 4 060 | 4 275 |
| | | | $I_e^0$ | 1 711 | 1 868 | 2 026 | 2 185 | 2 345 | 2 505 | 2 665 | 2 828 | 2 931 | 3 156 | 3 319 |
| 23. Подмосковный бассейн | — | Б | $I_z^0$ | 1 679 | 1 836 | 1 997 | 2 157 | 2 320 | 2 483 | 2 648 | 2 814 | 2 980 | 3 147 | 3 314 |
| | | | $I_e^0$ | 1 246 | 1 361 | 1 476 | 1 591 | 1 708 | 1 825 | 1 942 | 2 061 | 2 179 | 2 299 | 2 418 |

Key: 12. The Kuznetsk Basin. (12a). Kemerovo. (14a). Leninist. (16a). Prokop'yevsko-Kiselevskiy (Stalinugol', Prokop'yevskugol', Kaganovichugol'). (17a). the same. (19a). Aralichevskiy. 21. Karaganda basin. 22. the same 23. Moscow basin. 24. Pechora basin. 26. UkrSSR right bank. (26a). Alexandrine, Zvenigorodskiy, Korostyshevskiy, etc. 27. Western Ukraine. (27a). Zolochevskiy (Trostyanetskiy). (28a). Kolomyyskiy. 29. Transcarpathian Ukraine. (29a). Mukachevskiy (Il'nitskiy). 30. Bashkir ASSR. (30a). Babayevskiy Yermolayevskiy section/cut). 31. Urals. (31a). Kizelovskiy. (34a). Theological. (35a). Chelyabinsk.

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24. Печорский бассейн | — | ПЖ | $I_г^0$ | 228 | 463 | 703 | 951 | 1 206 | 1 468 | 1 736 | 2 009 | 2 287 | 2 571 | 2 858 |
| | | | $I_в^0$ | 204 | 410 | 620 | 834 | 1 053 | 1 277 | 1 505 | 1 737 | 1 973 | 2 212 | 2 454 |
| 25. » » | — | Д | $I_г^0$ | 175 | 356 | 541 | 732 | 928 | 1 129 | 1 336 | 1 546 | 1 760 | 1 979 | 2 201 |
| | | | $I_в^0$ | 153 | 307 | 464 | 624 | 788 | 956 | 1 127 | 1 301 | 1 477 | 1 656 | 1 837 |
| 26. УССР Правобережье | 26a Александрийское, Звенигородское, Коростышевское и др. | Б | $I_г^0$ | 104 | 211 | 320 | 433 | 550 | 669 | 792 | 918 | 1 046 | 1 177 | 1 310 |
| | | | $I_в^0$ | 71 | 149 | 222 | 296 | 372 | 449 | 521 | 601 | 683 | 766 | 849 |
| 27. Западная Украина | 27a Золочевское (Тростянецкое) | Б | $I_г^0$ | 121 | 246 | 374 | 506 | 642 | 781 | 924 | 1 070 | 1 219 | 1 371 | 1 526 |
| | | | $I_в^0$ | 92 | 186 | 281 | 377 | 477 | 578 | 682 | 787 | 893 | 1 001 | 1 111 |
| 28. » » | 28a Коломыйское | Б | $I_г^0$ | 150 | 304 | 462 | 625 | 792 | 964 | 1 141 | 1 321 | 1 505 | 1 691 | 1 881 |
| | | | $I_в^0$ | 125 | 251 | 373 | 510 | 644 | 781 | 920 | 1 062 | 1 206 | 1 352 | 1 501 |
| 29. Закарпатская Украина | 29a Мукачевское (Ильницкое) | Б | $I_г^0$ | 92 | 186 | 282 | 382 | 484 | 589 | 698 | 808 | 921 | 1 037 | 1 154 |
| | | | $I_в^0$ | 62 | 125 | 189 | 254 | 321 | 389 | 459 | 530 | 602 | 674 | 748 |
| 30. Башкирская АССР | 30a Бабаевское (Ермолаевский разрез) | Б | $I_г^0$ | 123 | 250 | 380 | 515 | 653 | 794 | 940 | 1 089 | 1 241 | 1 396 | 1 554 |
| | | | $I_в^0$ | 88 | 177 | 268 | 360 | 455 | 552 | 650 | 751 | 852 | 955 | 1 060 |
| 31. Урал | 31a Кизеловское | Г | $I_г^0$ | 196 | 397 | 603 | 816 | 1 034 | 1 258 | 1 488 | 1 722 | 1 961 | 2 204 | 2 450 |
| | | | $I_в^0$ | 175 | 351 | 531 | 714 | 902 | 1 094 | 1 290 | 1 488 | 1 690 | 1 895 | 2 102 |
| 32. » | » | Д | $I_г^0$ | 197 | 399 | 606 | 820 | 1 040 | 1 265 | 1 496 | 1 732 | 1 972 | 2 216 | 2 464 |
| | | | $I_в^0$ | 175 | 351 | 531 | 715 | 903 | 1 095 | 1 291 | 1 490 | 1 692 | 1 896 | 2 104 |
| 33. » | » | ППМ | $I_г^0$ | 158 | 320 | 486 | 658 | 834 | 1 015 | 1 200 | 1 389 | 1 582 | 1 778 | 1 977 |
| | | | $I_в^0$ | 139 | 279 | 421 | 567 | 716 | 868 | 1 024 | 1 181 | 1 342 | 1 504 | 1 669 |
| 34. » | 34a Богословское | Б | $I_г^0$ | 130 | 264 | 402 | 544 | 689 | 839 | 993 | 1 150 | 1 310 | 1 473 | 1 638 |
| | | | $I_в^0$ | 103 | 208 | 315 | 423 | 534 | 648 | 764 | 882 | 1 002 | 1 123 | 1 246 |
| 35. » | 35a Челябинское | Б | $I_г^0$ | 157 | 318 | 483 | 653 | 829 | 1 008 | 1 193 | 1 381 | 1 573 | 1 768 | 1 967 |
| | | | $I_в^0$ | 132 | 266 | 402 | 541 | 684 | 829 | 977 | 1 128 | 1 281 | 1 436 | 1 594 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24. Печорский бассейн | — | ПЖ | $I_г^0$ | 3 149 | 3 441 | 3 740 | 4 037 | 4 338 | 4 641 | 4 945 | 5 251 | 5 558 | 5 866 | 6 174 |
| | | | $I_в^0$ | 2 698 | 2 945 | 3 195 | 3 445 | 3 697 | 3 950 | 4 203 | 4 460 | 4 717 | 4 977 | 5 234 |
| 25. » » | — | Д | $I_г^0$ | 2 425 | 2 650 | 2 880 | 3 110 | 3 341 | 3 576 | 3 810 | 4 047 | 4 284 | 4 521 | 4 760 |
| | | | $I_в^0$ | 2 020 | 2 205 | 2 392 | 2 579 | 2 768 | 2 958 | 3 147 | 3 339 | 3 531 | 3 726 | 3 918 |
| 26. УССР Правобережье | 26a Александрийское, Звенигородское, Коростышевское и др. | Б | $I_г^0$ | 1 445 | 1 581 | 1 720 | 1 860 | 2 001 | 2 144 | 2 287 | 2 432 | 2 577 | 2 723 | 2 870 |
| | | | $I_в^0$ | 934 | 1 020 | 1 106 | 1 193 | 1 280 | 1 368 | 1 455 | 1 544 | 1 633 | 1 723 | 1 812 |
| 27. Западная Украина | 27a Золочевское (Тростянецкое) | Б | $I_г^0$ | 1 682 | 1 840 | 2 001 | 2 162 | 2 324 | 2 489 | 2 654 | 2 821 | 2 988 | 3 155 | 3 323 |
| | | | $I_в^0$ | 1 222 | 1 334 | 1 447 | 1 560 | 1 674 | 1 789 | 1 903 | 2 020 | 2 136 | 2 254 | 2 370 |
| 28. » » | 28a Коломыйское | Б | $I_г^0$ | 2 073 | 2 266 | 2 463 | 2 661 | 2 860 | 3 060 | 3 262 | 3 466 | 3 670 | 3 874 | 4 079 |
| | | | $I_в^0$ | 1 650 | 1 801 | 1 953 | 2 106 | 2 261 | 2 415 | 2 570 | 2 727 | 2 884 | 3 043 | 3 200 |
| 29. Закарпатская Украина | 29a Мукачевское (Ильницкое) | Б | $I_г^0$ | 1 273 | 1 393 | 1 515 | 1 638 | 1 763 | 1 888 | 2 015 | 2 142 | 2 270 | 2 398 | 2 527 |
| | | | $I_в^0$ | 823 | 898 | 974 | 1 050 | 1 127 | 1 204 | 1 282 | 1 360 | 1 438 | 1 518 | 1 596 |
| 30. Башкирская АССР | 30a Бабаевское (Ермолаевский разрез) | Б | $I_г^0$ | 1 713 | 1 875 | 2 039 | 2 204 | 2 371 | 2 539 | 2 709 | 2 880 | 3 051 | 3 223 | 3 396 |
| | | | $I_в^0$ | 1 166 | 1 272 | 1 380 | 1 488 | 1 597 | 1 707 | 1 816 | 1 927 | 2 033 | 2 150 | 2 261 |
| 31. Урал | 31a Кизеловское | Г | $I_г^0$ | 2 699 | 2 950 | 3 206 | 3 461 | 3 719 | 3 979 | 4 240 | 4 503 | 4 766 | 5 030 | 5 294 |
| | | | $I_в^0$ | 2 311 | 2 523 | 2 737 | 2 951 | 3 168 | 3 384 | 3 601 | 3 821 | 4 041 | 4 264 | 4 484 |
| 32. » | » | Д | $I_г^0$ | 2 715 | 2 967 | 3 224 | 3 481 | 3 740 | 4 002 | 4 264 | 4 529 | 4 794 | 5 059 | 5 326 |
| | | | $I_в^0$ | 2 314 | 2 526 | 2 739 | 2 954 | 3 170 | 3 387 | 3 605 | 3 825 | 4 045 | 4 268 | 4 488 |
| 33. » | » | ППМ | $I_г^0$ | 2 178 | 2 381 | 2 588 | 2 794 | 3 002 | 3 213 | 3 423 | 3 636 | 3 849 | 4 062 | 4 276 |
| | | | $I_в^0$ | 1 835 | 2 003 | 2 173 | 2 343 | 2 514 | 2 686 | 2 859 | 3 033 | 3 208 | 3 385 | 3 559 |
| 34. » | 34a Богословское | Б | $I_г^0$ | 1 806 | 1 975 | 2 147 | 2 320 | 2 493 | 2 669 | 2 846 | 3 024 | 3 202 | 3 381 | 3 561 |
| | | | $I_в^0$ | 1 369 | 1 495 | 1 622 | 1 749 | 1 877 | 2 005 | 2 134 | 2 264 | 2 394 | 2 526 | 2 657 |
| 35. » | 35a Челябинское | Б | $I_г^0$ | 2 167 | 2 369 | 2 575 | 2 781 | 2 988 | 3 198 | 3 408 | 3 621 | 3 833 | 4 046 | 4 260 |
| | | | $I_в^0$ | 1 752 | 1 913 | 2 074 | 2 236 | 2 401 | 2 565 | 2 729 | 2 896 | 3 063 | 3 232 | 3 399 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 36. Урал | Буланашское 36a | Г | $I_r^0$ | 215 | 436 | 663 | 897 | 1 137 | 1 383 | 1 636 | 1 894 | 2 156 | 2 424 | 2 695 |
| | | | $I_e^0$ | 190 | 381 | 577 | 776 | 979 | 1 188 | 1 401 | 1 617 | 1 836 | 2 053 | 2 283 |
| 37. " | Егоршинское 37a | А | $I_r^0$ | 228 | 463 | 703 | 951 | 1 206 | 1 468 | 1 735 | 2 010 | 2 288 | 2 571 | 2 859 |
| | | | $I_e^0$ | 207 | 417 | 630 | 848 | 1 070 | 1 298 | 1 531 | 1 766 | 2 006 | 2 249 | 2 495 |
| 38. Грузинская ССР | Ткварчельское 38a | ПЖ | $I_r^0$ | 169 | 342 | 520 | 703 | 892 | 1 085 | 1 283 | 1 486 | 1 691 | 1 901 | 2 114 |
| | | | $I_e^0$ | 148 | 297 | 449 | 604 | 763 | 925 | 1 091 | 1 259 | 1 429 | 1 602 | 1 778 |
| 39. " " | Ткибульское 39a | Г | $I_r^0$ | 181 | 367 | 559 | 756 | 958 | 1 166 | 1 379 | 1 597 | 1 818 | 2 043 | 2 272 |
| | | | $I_e^0$ | 153 | 317 | 480 | 645 | 815 | 989 | 1 166 | 1 345 | 1 528 | 1 712 | 1 900 |
| 40. " " | Гелати 40a | Б | $I_r^0$ | 128 | 260 | 395 | 534 | 678 | 825 | 975 | 1 129 | 1 286 | 1 446 | 1 608 |
| | | | $I_e^0$ | 109 | 220 | 332 | 447 | 564 | 684 | 807 | 931 | 1 058 | 1 185 | 1 315 |
| 41. " " | Ахалцихское 41a | Б | $I_r^0$ | 112 | 227 | 345 | 466 | 591 | 719 | 851 | 985 | 1 122 | 1 262 | 1 404 |
| | | | $I_e^0$ | 90 | 182 | 275 | 369 | 467 | 566 | 667 | 770 | 874 | 980 | 1 088 |
| 42. Казахская ССР | 42a Иртышское (Экибастуз) | СС | $I_r^0$ | 162 | 329 | 500 | 672 | 857 | 1 043 | 1 234 | 1 428 | 1 626 | 1 828 | 2 032 |
| | | | $I_e^0$ | 143 | 287 | 434 | 584 | 737 | 894 | 1 054 | 1 216 | 1 381 | 1 548 | 1 718 |
| 43. " " | Ленгеровское 43a | Б | $I_r^0$ | 167 | 339 | 516 | 698 | 885 | 1 078 | 1 275 | 1 476 | 1 681 | 1 890 | 2 102 |
| | | | $I_e^0$ | 140 | 281 | 424 | 571 | 721 | 874 | 1 031 | 1 190 | 1 351 | 1 514 | 1 680 |
| 44. Узбекская ССР | Ангрен 44a | Б | $I_r^0$ | 157 | 318 | 483 | 654 | 830 | 1 010 | 1 195 | 1 384 | 1 576 | 1 772 | 1 971 |
| | | | $I_e^0$ | 127 | 256 | 387 | 521 | 658 | 798 | 941 | 1 086 | 1 233 | 1 382 | 1 534 |
| 45. Киргизская ССР | Кизыл-Кия 45a | Б | $I_r^0$ | 171 | 346 | 526 | 712 | 903 | 1 100 | 1 301 | 1 506 | 1 715 | 1 928 | 2 145 |
| | | | $I_e^0$ | 142 | 286 | 433 | 582 | 735 | 891 | 1 051 | 1 213 | 1 377 | 1 544 | 1 713 |
| 46. " " | Сулюкта 46a | Б | $I_r^0$ | 183 | 372 | 566 | 766 | 972 | 1 183 | 1 399 | 1 620 | 1 845 | 2 074 | 2 306 |
| | | | $I_e^0$ | 156 | 315 | 476 | 640 | 808 | 980 | 1 156 | 1 334 | 1 515 | 1 698 | 1 884 |
| 47. " " | Кок-Янгак 47a | Д | $I_r^0$ | 195 | 396 | 602 | 814 | 1 033 | 1 257 | 1 487 | 1 721 | 1 960 | 2 203 | 2 450 |
| | | | $I_e^0$ | 163 | 357 | 515 | 693 | 874 | 1 060 | 1 250 | 1 443 | 1 639 | 1 837 | 2 038 |

Key: 36. Urals. (36a). Eulanashskiy. (37a). Yegorshinskiy. 38. Georgian SSR. (38a). Tkvarchel'skiy. (39a). Tkvibul'skiy. (40a). Gelati. (41a). Akhaltsikhskiy. 42. Kazakh SSR. (42a). Irtysh (Ekibastuz). (43a). Lergerorskiy. 44. Uzbek SSR. (44a). Angren. 45. Kirghiz SSR. (45a). Kyzyl-Kiya. (46a). Sulyukta. (47a). Kok-Yangak.

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 36. Урал | Буланашское 36a | Г | $I_r^0$ | 2 969 | 3 246 | 3 527 | 3 808 | 4 091 | 4 378 | 4 665 | 4 954 | 5 245 | 5 535 | 5 826 |
| | | | $I_e^0$ | 2 510 | 2 741 | 2 972 | 3 205 | 3 440 | 3 675 | 3 911 | 4 150 | 4 388 | 4 631 | 4 870 |
| 37. " | Егоршинское 37a | А | $I_r^0$ | 3 149 | 3 441 | 3 739 | 4 036 | 4 335 | 4 638 | 4 941 | 5 246 | 5 553 | 5 859 | 6 166 |
| | | | $I_e^0$ | 2 743 | 2 995 | 3 248 | 3 503 | 3 759 | 4 016 | 4 274 | 4 535 | 4 796 | 5 060 | 5 322 |
| 38. Грузинская ССР | Ткварчельское 38a | ПЖ | $I_r^0$ | 2 329 | 2 546 | 2 767 | 2 988 | 3 210 | 3 435 | 3 660 | 3 888 | 4 116 | 4 344 | 4 573 |
| | | | $I_e^0$ | 1 955 | 2 134 | 2 314 | 2 496 | 2 679 | 2 862 | 3 045 | 3 231 | 3 417 | 3 606 | 3 792 |
| 39. " " | Ткибульское 39a | Г | $I_r^0$ | 2 503 | 2 737 | 2 974 | 3 211 | 3 451 | 3 692 | 3 935 | 4 179 | 4 425 | 4 669 | 4 916 |
| | | | $I_e^0$ | 2 089 | 2 281 | 2 473 | 2 667 | 2 863 | 3 059 | 3 255 | 3 453 | 3 652 | 3 854 | 4 053 |
| 40. " " | Гелати 40a | Б | $I_r^0$ | 1 771 | 1 937 | 2 105 | 2 273 | 2 442 | 2 614 | 2 786 | 2 959 | 3 133 | 3 306 | 3 481 |
| | | | $I_e^0$ | 1 446 | 1 579 | 1 712 | 1 847 | 1 982 | 2 117 | 2 253 | 2 391 | 2 528 | 2 668 | 2 805 |
| 41. " " | Ахалцихское 41a | Б | $I_r^0$ | 1 547 | 1 692 | 1 839 | 1 987 | 2 136 | 2 286 | 2 437 | 2 590 | 2 743 | 2 895 | 3 049 |
| | | | $I_e^0$ | 1 196 | 1 305 | 1 416 | 1 527 | 1 629 | 1 751 | 1 863 | 1 977 | 2 090 | 2 206 | 2 320 |
| 42. Казахская ССР | 42a Иртышское (Экибастуз) | СС | $I_r^0$ | 2 239 | 2 447 | 2 659 | 2 871 | 3 085 | 3 301 | 3 536 | 3 751 | 3 955 | 4 173 | 4 393 |
| | | | $I_e^0$ | 1 888 | 2 062 | 2 237 | 2 411 | 2 568 | 2 765 | 2 942 | 3 122 | 3 301 | 3 484 | 3 664 |
| 43. " " | Ленгеровское 43a | Б | $I_r^0$ | 2 316 | 2 533 | 2 753 | 2 973 | 3 195 | 3 420 | 3 645 | 3 872 | 4 100 | 4 328 | 4 557 |
| | | | $I_e^0$ | 1 847 | 2 017 | 2 187 | 2 359 | 2 532 | 2 705 | 2 878 | 3 053 | 3 230 | 3 408 | 3 584 |
| 44. Узбекская ССР | Ангрен 44a | Б | $I_r^0$ | 2 173 | 2 376 | 2 583 | 2 769 | 2 999 | 3 209 | 3 421 | 3 635 | 3 849 | 4 063 | 4 279 |
| | | | $I_e^0$ | 1 686 | 1 841 | 1 996 | 2 153 | 2 311 | 2 469 | 2 627 | 2 788 | 2 948 | 3 111 | 3 271 |
| 45. Киргизская ССР | Кизыл-Кия 45a | Б | $I_r^0$ | 2 364 | 2 584 | 2 809 | 3 033 | 3 260 | 3 489 | 3 719 | 3 950 | 4 183 | 4 415 | 4 649 |
| | | | $I_e^0$ | 1 883 | 2 056 | 2 230 | 2 405 | 2 581 | 2 758 | 2 934 | 3 114 | 3 293 | 3 474 | 3 654 |
| 46. " " | Сулюкта 46a | Б | $I_r^0$ | 2 541 | 2 778 | 3 019 | 3 260 | 3 503 | 3 749 | 3 995 | 4 244 | 4 493 | 4 742 | 4 092 |
| | | | $I_e^0$ | 2 071 | 2 261 | 2 453 | 2 645 | 2 839 | 3 033 | 3 227 | 3 424 | 3 621 | 3 821 | 4 019 |
| 47. " " | Кок-Янгак 47a | Д | $I_r^0$ | 2 699 | 2 951 | 3 207 | 3 463 | 3 721 | 3 981 | 4 243 | 4 506 | 4 770 | 5 035 | 5 301 |
| | | | $I_e^0$ | 2 241 | 2 446 | 2 653 | 2 861 | 3 070 | 3 280 | 3 491 | 3 704 | 3 917 | 4 133 | 4 347 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 48. Киргизская ССР | Ташкумыр 48a | Д | $I_z^0$ | 216 | 437 | 665 | 900 | 1 141 | 1 388 | 1 642 | 1 901 | 2 164 | 2 433 | 2 705 |
| | | | $I_e^0$ | 188 | 379 | 573 | 771 | 973 | 1 181 | 1 392 | 1 607 | 1 825 | 2 045 | 2 269 |
| 49. Таджикская ССР | Шураб 49a | Б | $I_z^0$ | 169 | 344 | 523 | 707 | 897 | 1 092 | 1 292 | 1 496 | 1 703 | 1 915 | 2 130 |
| | | | $I_e^0$ | 142 | 285 | 430 | 579 | 731 | 886 | 1 045 | 1 206 | 1 370 | 1 535 | 1 704 |
| 50. Красноярский край | Канское 50a | Б | $I_z^0$ | 160 | 325 | 494 | 668 | 847 | 1 031 | 1 220 | 1 412 | 1 609 | 1 809 | 2 012 |
| | | | $I_e^0$ | 129 | 260 | 393 | 529 | 668 | 810 | 955 | 1 102 | 1 251 | 1 402 | 1 556 |
| 51. Хакасская А. О. | Минусинское 51a | Д | $I_z^0$ | 259 | 526 | 799 | 1 031 | 1 371 | 1 668 | 1 972 | 2 283 | 2 599 | 2 921 | 3 248 |
| | | | $I_e^0$ | 230 | 463 | 701 | 942 | 1 190 | 1 443 | 1 702 | 1 964 | 2 231 | 2 500 | 2 774 |
| 52. Иркутская обл. | Черемховское 52a | Д | $I_z^0$ | 189 | 383 | 532 | 787 | 999 | 1 215 | 1 437 | 1 664 | 1 894 | 2 130 | 2 368 |
| | | | $I_e^0$ | 163 | 329 | 497 | 669 | 844 | 1 024 | 1 207 | 1 393 | 1 583 | 1 774 | 1 968 |
| 53. Бурят-Монгольская АССР | Гусино-Озерское 53a | Б | $I_z^0$ | 176 | 357 | 543 | 735 | 932 | 1 134 | 1 342 | 1 554 | 1 769 | 1 939 | 2 212 |
| | | | $I_e^0$ | 149 | 299 | 452 | 609 | 769 | 932 | 1 099 | 1 268 | 1 440 | 1 615 | 1 792 |
| 54. Читинская обл. | Тарбагатайское 54a | Б | $I_z^0$ | 177 | 359 | 546 | 738 | 937 | 1 140 | 1 348 | 1 562 | 1 778 | 1 999 | 2 224 |
| | | | $I_e^0$ | 149 | 300 | 453 | 610 | 770 | 934 | 1 101 | 1 271 | 1 443 | 1 617 | 1 795 |
| 55. » » | Черновское 55a | Б | $I_z^0$ | 172 | 349 | 530 | 717 | 910 | 1 107 | 1 310 | 1 517 | 1 727 | 1 943 | 2 161 |
| | | | $I_e^0$ | 140 | 282 | 426 | 574 | 724 | 879 | 1 036 | 1 196 | 1 358 | 1 522 | 1 689 |
| 56. » » | Арабагарское 56a | Б | $I_z^0$ | 159 | 323 | 491 | 665 | 843 | 1 026 | 1 214 | 1 406 | 1 601 | 1 801 | 2 002 |
| | | | $I_e^0$ | 131 | 264 | 399 | 537 | 678 | 822 | 969 | 1 118 | 1 270 | 1 424 | 1 580 |
| 57. » » | Букачачинское 57a | Г | $I_z^0$ | 240 | 486 | 739 | 1 000 | 1 268 | 1 543 | 1 825 | 2 112 | 2 405 | 2 703 | 3 005 |
| | | | $I_e^0$ | 213 | 429 | 648 | 872 | 1 101 | 1 335 | 1 574 | 1 816 | 2 063 | 2 312 | 2 566 |
| 58. » » | » | Д | $I_z^0$ | 224 | 454 | 690 | 933 | 1 183 | 1 440 | 1 703 | 1 972 | 2 245 | 2 523 | 2 806 |
| | | | $I_e^0$ | 195 | 393 | 594 | 800 | 1 010 | 1 225 | 1 444 | 1 666 | 1 892 | 2 121 | 2 354 |
| 59. Хабаровский край | Райчихинское 59a | Б | $I_z^0$ | 144 | 291 | 443 | 600 | 761 | 926 | 1 095 | 1 269 | 1 445 | 1 625 | 1 808 |
| | | | $I_e^0$ | 112 | 226 | 342 | 460 | 581 | 705 | 831 | [illegible] | 1 089 | 1 220 | 1 354 |

Key: 48. Kirghiz SSR. (48a). Tashkumyr. 49. Tadzhik SSR. (49a). Shurab. 50. Krasnoyarsk region. (50a). Kanskiy. 51. A. O. Khakasskaya. (51a). Minusinsk. 52. Irkutsk Obl. (52a). Cheremkhovskiy. 53. Buryat-Mongolian ASSR. (53a). Goose-ozerskoe. 54. Chita Obl. (54a). Tarbagatayskiy. (55a). Chernovskiy. (56a). Arabagarskiy. (57a). Bukachachinskiy. 59. Khabarovsk region. (59a). Baychikhinskiy.

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 48. Киргизская ССР | Ташкумыр 48a | Д | $I_z^0$ | 2 980 | 3 258 | 3 541 | 3 823 | 4 107 | 4 395 | 4 683 | 4 974 | 5 265 | 5 557 | 5 850 |
| | | | $I_e^0$ | 2 495 | 2 724 | 2 954 | 3 186 | 3 419 | 3 653 | 3 887 | 4 124 | 4 362 | 4 602 | 4 840 |
| 49. Таджикская ССР | Шураб 49a | Б | $I_z^0$ | 2 347 | 2 566 | 2 789 | 3 012 | 3 237 | 3 463 | 3 692 | 3 922 | 4 153 | 4 384 | 4 616 |
| | | | $I_e^0$ | 1 873 | 2 045 | 2 218 | 2 392 | 2 567 | 2 742 | 2 918 | 3 096 | 3 274 | 3 455 | 3 633 |
| 50. Красноярский край | Канское 50a | Б | $I_z^0$ | 2 218 | 2 425 | 2 636 | 2 848 | 3 061 | 3 277 | 3 493 | 3 712 | 3 931 | 4 139 | 4 370 |
| | | | $I_e^0$ | 1 711 | 1 868 | 2 026 | 2 185 | 2 345 | 2 505 | 2 665 | 2 828 | 2 991 | 3 156 | 3 319 |
| 51. Хакасская А. О. | Минусинское 51a | Д | $I_z^0$ | 3 578 | 3 911 | 4 250 | 4 589 | 4 930 | 5 275 | 5 622 | 5 970 | 6 320 | 6 670 | 7 021 |
| | | | $I_e^0$ | 3 050 | 3 330 | 3 611 | 3 895 | 4 180 | 4 466 | 4 752 | 5 042 | 5 333 | 5 627 | 5 917 |
| 52. Иркутская обл. | Черемховское 52a | Д | $I_z^0$ | 2 609 | 2 852 | 3 100 | 3 347 | 3 597 | 3 849 | 4 102 | 4 357 | 4 612 | 4 868 | 5 125 |
| | | | $I_e^0$ | 2 164 | 2 362 | 2 562 | 2 763 | 2 965 | 3 168 | 3 371 | 3 578 | 3 783 | 3 992 | 4 198 |
| 53. Бурят-Монгольская ССР | Гусино-Озерское 53a | Б | $I_z^0$ | 2 438 | 2 665 | 2 897 | 3 129 | 3 362 | 3 598 | 3 835 | 4 073 | 4 313 | 4 552 | 4 793 |
| | | | $I_e^0$ | 1 964 | 2 150 | 2 332 | 2 515 | 2 699 | 2 884 | 3 069 | 3 256 | 3 444 | 3 633 | 3 821 |
| 54. Читинская обл. | Тарбагатайское 54a | Б | $I_z^0$ | 2 449 | 2 678 | 2 911 | 3 143 | 3 378 | 3 616 | 3 854 | 4 094 | 4 335 | 4 575 | 4 817 |
| | | | $I_e^0$ | 1 973 | 2 154 | 2 336 | 2 519 | 2 704 | 2 889 | 3 074 | 3 262 | 3 449 | 3 640 | 3 828 |
| 55. . . | Черновское 55a | Б | $I_z^0$ | 2 382 | 2 604 | 2 831 | 3 059 | 3 287 | 3 518 | 3 751 | 3 985 | 4 220 | 4 455 | 4 691 |
| | | | $I_e^0$ | 1 857 | 2 027 | 2 198 | 2 371 | 2 544 | 2 718 | 2 893 | 3 069 | 3 246 | 3 425 | 3 602 |
| 56. . . | Арабагарское 56a | Б | $I_z^0$ | 2 207 | 2 413 | 2 623 | 2 833 | 3 045 | 3 259 | 3 474 | 3 691 | 3 908 | 4 125 | 4 344 |
| | | | $I_e^0$ | 1 737 | 1 896 | 2 057 | 2 218 | 2 380 | 2 543 | 2 706 | 2 871 | 3 036 | 3 204 | 3 369 |
| 57. . . | Букачачинское 57a | Г | $I_z^0$ | 3 311 | 3 619 | 3 931 | 4 245 | 4 563 | 4 880 | 5 200 | 5 523 | 5 846 | 6 169 | 6 494 |
| | | | $I_e^0$ | 2 821 | 3 079 | 3 340 | 3 602 | 3 865 | 4 130 | 4 395 | 4 663 | 4 931 | 5 203 | 5 472 |
| 58. . . | . | Д | $I_z^0$ | 3 091 | 3 379 | 3 672 | 3 965 | 4 260 | 4 559 | 4 858 | 5 160 | 5 462 | 5 765 | 6 069 |
| | | | $I_e^0$ | 2 588 | 2 825 | 3 064 | 3 304 | 3 546 | 3 789 | 4 032 | 4 278 | 4 524 | 4 774 | 5 020 |
| 59. Хабаровский край | Райчихинское 59a | Б | $I_z^0$ | 1 993 | 2 180 | 2 370 | 2 560 | 2 753 | 2 947 | 3 142 | 3 339 | 3 535 | 3 733 | 3 932 |
| | | | $I_e^0$ | 1 489 | 1 625 | 1 763 | 1 901 | 2 040 | 2 180 | 2 320 | 2 461 | 2 603 | 2 747 | 2 888 |

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 60. Хабаровский край | 60a Киадинское | Б | $t_г^0$ | 148 | 301 | 458 | 619 | 785 | 956 | 1 131 | 1 309 | 1 491 | 1 677 | 1 866 |
| | | | $t_в^0$ | 118 | 238 | 360 | 485 | 612 | 742 | 875 | 1 010 | 1 147 | 1 285 | 1 426 |
| 61. » » | 61a Ургальское (Бурея) | Г | $t_г^0$ | 189 | 382 | 581 | 786 | 997 | 1 213 | 1 435 | 1 661 | 1 891 | 2 125 | 2 363 |
| | | | $t_в^0$ | 167 | 336 | 508 | 684 | 863 | 1 047 | 1 235 | 1 425 | 1 618 | 1 814 | 2 013 |
| 62. Приморский край | 62a Сучанское | Г | $t_г^0$ | 199 | 403 | 612 | 828 | 1 050 | 1 278 | 1 512 | 1 750 | 1 992 | 2 239 | 2 490 |
| | | | $t_в^0$ | 177 | 356 | 538 | 724 | 914 | 1 109 | 1 307 | 1 509 | 1 714 | 1 921 | 2 131 |
| 63. » » | » | ПЖ | $t_г^0$ | 222 | 450 | 684 | 925 | 1 173 | 1 428 | 1 689 | 1 954 | 2 225 | 2 501 | 2 781 |
| | | | $t_в^0$ | 199 | 400 | 605 | 814 | 1 028 | 1 246 | 1 469 | 1 696 | 1 926 | 2 159 | 2 395 |
| 64. » » | » | Т | $t_г^0$ | 220 | 446 | 679 | 918 | 1 165 | 1 417 | 1 676 | 1 940 | 2 209 | 2 482 | 2 760 |
| | | | $t_в^0$ | 199 | 401 | 606 | 815 | 1 029 | 1 248 | 1 472 | 1 699 | 1 929 | 2 162 | 2 399 |
| 65. » » | 65a Артемовское | Б | $t_г^0$ | 141 | 285 | 434 | 587 | 744 | 906 | 1 071 | 1 241 | 1 413 | 1 539 | 1 768 |
| | | | $t_в^0$ | 113 | 227 | 343 | 462 | 584 | 708 | 834 | 963 | 1 094 | 1 226 | 1 360 |
| 66. » » | 66a Тавричанское | Б | $t_г^0$ | 177 | 359 | 545 | 738 | 936 | 1 139 | 1 347 | 1 559 | 1 775 | 1 996 | 2 219 |
| | | | $t_в^0$ | 152 | 305 | 461 | 620 | 783 | 950 | 1 120 | 1 292 | 1 468 | 1 645 | 1 826 |
| 67. » » | 67a Подгородненское | Т | $t_г^0$ | 176 | 357 | 544 | 735 | 932 | 1 135 | 1 342 | 1 553 | 1 768 | 1 937 | 2 210 |
| | | | $t_в^0$ | 159 | 319 | 482 | 649 | 820 | 994 | 1 172 | 1 353 | 1 536 | 1 722 | 1 910 |
| 68. » » | 68a Ворошиловское | СС | $t_г^0$ | 168 | 342 | 519 | 703 | 891 | 1 084 | 1 282 | 1 484 | 1 689 | 1 899 | 2 111 |
| | | | $t_в^0$ | 150 | 302 | 457 | 615 | 777 | 942 | 1 110 | 1 282 | 1 455 | 1 631 | 1 810 |
| 69. » » | 69a Липовецкое | Д | $t_г^0$ | 181 | 367 | 554 | 754 | 956 | 1 163 | 1 376 | 1 593 | 1 814 | 2 039 | 2 267 |
| | | | $t_в^0$ | 158 | 317 | 479 | 645 | 814 | 987 | 1 164 | 1 344 | 1 526 | 1 710 | 1 898 |
| (g) Горючие сланцы* | | | | | | | | | | | | | | |
| 70. Эстонская ССР | — | — | $t_г^0$ | 117 | 237 | 360 | 486 | 617 | 750 | 888 | 1 028 | 1 171 | 1 317 | 1 465 |
| | | | $t_в^0$ | 95 | 190 | 287 | 386 | 488 | 592 | 698 | 806 | 915 | 1 025 | 1 138 |

Key: 60. Khabarovsk regicn. (60a). Kivdinskiy. (61a). Urgal'skiy (Bureya). 62. Seaside regicn. (62a). Suchanskiy. (65a). Artemcvskiy. (66a). Tavrichanskiy. (67a). Podgorodnenskiy. (68a). Voroshilovskiy. (69a). Lipovetskiy. (g). Bituminous shale *. 70. Estcnian SSR.

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 60. Хабаровский край | Кивдинское 60a | Б | $I_{г}^{0}$ | 2 056 | 2 249 | 2 445 | 2 641 | 2 839 | 3 039 | 3 240 | 3 443 | 3 646 | 3 849 | 4 054 |
| | | | $I_{в}^{0}$ | 1 568 | 1 712 | 1 857 | 2 002 | 2 149 | 2 296 | 2 443 | 2 592 | 2 741 | 2 893 | 3 042 |
| 61. . . | Ургальское (Бурея) 61a | Г | $I_{г}^{0}$ | 2 603 | 2 845 | 3 092 | 3 338 | 3 537 | 3 837 | 4 039 | 4 343 | 4 597 | 4 851 | 5 107 |
| | | | $I_{в}^{0}$ | 2 213 | 2 415 | 2 620 | 2 825 | 3 032 | 3 230 | 3 447 | 3 653 | 3 868 | 4 032 | 4 292 |
| 62. Приморский край | Сучанское 62a | Г | $I_{г}^{0}$ | 2 741 | 2 998 | 3 257 | 3 517 | 3 778 | 4 043 | 4 307 | 4 575 | 4 842 | 5 110 | 5 379 |
| | | | $I_{в}^{0}$ | 2 343 | 2 553 | 2 774 | 2 992 | 3 211 | 3 432 | 3 651 | 3 874 | 4 097 | 4 323 | 4 546 |
| 63. . . | . | ПЖ | $I_{г}^{0}$ | 3 063 | 3 348 | 3 637 | 3 925 | 4 221 | 4 514 | 4 810 | 5 108 | 5 406 | 5 704 | 6 005 |
| | | | $I_{в}^{0}$ | 2 633 | 2 875 | 3 118 | 3 363 | 3 609 | 3 856 | 4 103 | 4 354 | 4 604 | 4 858 | 5 109 |
| 64. . . | . | Т | $I_{г}^{0}$ | 3 040 | 3 322 | 3 609 | 3 896 | 4 186 | 4 478 | 4 771 | 5 066 | 5 352 | 5 657 | 5 954 |
| | | | $I_{в}^{0}$ | 2 638 | 2 860 | 3 124 | 3 368 | 3 615 | 3 862 | 4 110 | 4 361 | 4 612 | 4 867 | 5 118 |
| 65. . . | Артемовское 65a | Б | $I_{г}^{0}$ | 1 948 | 2 131 | 2 316 | 2 502 | 2 691 | 2 880 | 3 070 | 3 262 | 3 454 | 3 647 | 3 841 |
| | | | $I_{в}^{0}$ | 1 496 | 1 633 | 1 771 | 1 910 | 2 049 | 2 190 | 2 330 | 2 473 | 2 615 | 2 759 | 2 901 |
| 66. . . | Тавричанское 66a | Б | $I_{г}^{0}$ | 2 445 | 2 673 | 2 905 | 3 138 | 3 372 | 3 608 | 3 845 | 4 084 | 4 324 | 4 564 | 4 805 |
| | | | $I_{в}^{0}$ | 2 007 | 2 191 | 2 376 | 2 563 | 2 750 | 2 939 | 3 127 | 3 318 | 3 509 | 3 702 | 3 893 |
| 67. . . | Подгородненское 67a | Т | $I_{г}^{0}$ | 2 434 | 2 660 | 2 890 | 3 120 | 3 352 | 3 586 | 3 821 | 4 058 | 4 295 | 4 532 | 4 770 |
| | | | $I_{в}^{0}$ | 2 100 | 2 293 | 2 487 | 2 682 | 2 878 | 3 075 | 3 272 | 3 472 | 3 672 | 3 875 | 4 074 |
| 68. . . | Ворошиловское 68a | СС | $I_{г}^{0}$ | 2 326 | 2 542 | 2 762 | 2 982 | 3 220 | 3 423 | 3 653 | 3 879 | 4 106 | 4 333 | 4 561 |
| | | | $I_{в}^{0}$ | 1 990 | 2 173 | 2 357 | 2 541 | 2 727 | 2 914 | 3 101 | 3 290 | 3 479 | 3 671 | 3 861 |
| 69. . . | Липовецкое 69a | Д | $I_{г}^{0}$ | 2 493 | 2 731 | 2 968 | 3 204 | 3 443 | 3 684 | 3 926 | 4 170 | 4 414 | 4 659 | 4 905 |
| | | | $I_{в}^{0}$ | 2 086 | 2 278 | 2 470 | 2 664 | 2 859 | 3 055 | 3 251 | 3 449 | 3 648 | 3 849 | 4 048 |
| 9 Горючие сланцы* | | | | | | | | | | | | | | |
| 70. Эстонская ССР | — | — | $I_{г}^{0}$ | 1 614 | 1 765 | 1 919 | 2 073 | 2 228 | 2 385 | 2 543 | 2 702 | 2 861 | 3 021 | 3 181 |
| | | | $I_{в}^{0}$ | 1 251 | 1 365 | 1 481 | 1 597 | 1 714 | 1 831 | 1 948 | 2 067 | 2 186 | 2 307 | 2 426 |

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 71. Ленинградская обл. | Гдовское (71a) | — | $I_{г}^{0}$ | 93 | 189 | 287 | 388 | 492 | 599 | 709 | 821 | 935 | 1 051 | 1 169 |
| | | | $I_{в}^{0}$ | 73 | 148 | 223 | 300 | 379 | 460 | 542 | 625 | 710 | 796 | 883 |
| 72. Куйбышевская обл. | Кашпирское (72a) | — | $I_{г}^{0}$ | 76 | 154 | 234 | 316 | 401 | 488 | 577 | 669 | 762 | 857 | 954 |
| | | | $I_{в}^{0}$ | 57 | 115 | 173 | 233 | 294 | 357 | 421 | 485 | 551 | 618 | 686 |
| 73. Саратовская обл. | Савельевское (73a) | — | $I_{г}^{0}$ | 72 | 146 | 222 | 301 | 381 | 464 | 549 | 636 | 725 | 815 | 907 |
| | | | $I_{в}^{0}$ | 54 | 108 | 164 | 220 | 278 | 337 | 397 | 459 | 521 | 584 | 648 |
| 74. » » | Озинское (74a) | — | $I_{г}^{0}$ | 73 | 149 | 226 | 306 | 388 | 473 | 559 | 648 | 738 | 830 | 923 |
| | | | $I_{в}^{0}$ | 56 | 110 | 167 | 224 | 283 | 343 | 405 | 467 | 531 | 595 | 660 |
| 75. Торф | — | (75a) Кусковой | $I_{г}^{0}$ | 130 | 264 | 401 | 542 | 687 | 837 | 990 | 1 147 | 1 307 | 1 470 | 1 636 |
| | | | $I_{в}^{0}$ | 95 | 192 | 290 | 390 | 492 | 597 | 703 | 812 | 922 | 1 033 | 1 147 |
| 76. » | — | (76a) Фрезерный | $I_{г}^{0}$ | 116 | 235 | 357 | 483 | 612 | 746 | 883 | 1 022 | 1 165 | 1 311 | 1 459 |
| | | | $I_{в}^{0}$ | 79 | 160 | 241 | 324 | 410 | 495 | 586 | 676 | 768 | 861 | 955 |
| 77. Дрова | — | — | $I_{г}^{0}$ | 126 | 255 | 388 | 525 | 667 | 812 | 960 | 1 113 | 1 268 | 1 427 | 1 588 |
| | | | $I_{в}^{0}$ | 89 | 179 | 271 | 364 | 460 | 558 | 657 | 759 | 862 | 966 | 1 072 |
| 78. Коксовая мелочь | — | — | $I_{г}^{0}$ | 211 | 427 | 650 | 880 | 1 116 | 1 358 | 1 607 | 1 860 | 2 118 | 2 381 | 2 647 |
| | | | $I_{в}^{0}$ | 187 | 376 | 569 | 765 | 966 | 1 171 | 1 381 | 1 594 | 1 810 | 2 029 | 2 252 |
| 79. Мазут | — | (79a) Малосернистый | $I_{г}^{0}$ | 365 | 738 | 1 121 | 1 516 | 1 921 | 2 337 | 2 763 | 3 193 | 3 641 | 4 092 | 4 550 |
| | | | $I_{в}^{0}$ | 325 | 654 | 989 | 1 330 | 1 680 | 2 037 | 2 402 | 2 772 | 3 148 | 3 528 | 3 915 |
| 80. » | — | (80a) Высокосернистый | $I_{г}^{0}$ | 360 | 728 | 1 107 | 1 496 | 1 895 | 2 306 | 2 727 | 3 156 | 3 592 | 4 038 | 4 489 |
| | | | $I_{в}^{0}$ | 321 | 646 | 976 | 1 313 | 1 658 | 2 011 | 2 371 | 2 736 | 3 107 | 3 483 | 3 865 |

Key: 71. Leningrad Obl. (71a). Gdovskiy. 72. Kuybyshev Obl. (72a). Kashpirskiy. 73. Saratov Obl. (73a). Savel'evskiy. (74a). Ozinskiy. 75. Peat. (75a). Cake. (76a). Milling. 77. Firewood. 78. Coke breeze. 79. Petroleum residue. (79a). Low-sulfur. (80a). High-sulphur.

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 71. Ленинградская обл. | Гдовское 71a | — | $I_{г}^{0}$ | 1 289 | 1 410 | 1 533 | 1 656 | 1 780 | 1 906 | 2 032 | 2 159 | 2 286 | 2 414 | 2 543 |
| | | | $I_{в}^{0}$ | 971 | 1 060 | 1 150 | 1 240 | 1 331 | 1 422 | 1 513 | 1 606 | 1 698 | 1 792 | 1 884 |
| 72. Куйбышевская обл. | Кашпирское 72a | — | $I_{г}^{0}$ | 1 051 | 1 150 | 1 251 | 1 351 | 1 453 | 1 556 | 1 659 | 1 764 | 1 868 | 1 973 | 2 078 |
| | | | $I_{в}^{0}$ | 754 | 823 | 893 | 963 | 1 033 | 1 104 | 1 175 | 1 246 | 1 318 | 1 391 | 1 462 |
| 73. Саратовская обл. | Савельевское 73a | — | $I_{г}^{0}$ | 1 000 | 1 094 | 1 190 | 1 286 | 1 383 | 1 480 | 1 579 | 1 678 | 1 778 | 1 877 | 1 978 |
| | | | $I_{в}^{0}$ | 712 | 777 | 843 | 909 | 976 | 1 042 | 1 109 | 1 177 | 1 245 | 1 313 | 1 381 |
| 74. " " | Озинское 74a | — | $I_{г}^{0}$ | 1 018 | 1 114 | 1 211 | 1 309 | 1 408 | 1 508 | 1 608 | 1 709 | 1 810 | 1 912 | 2 014 |
| | | | $I_{в}^{0}$ | 725 | 792 | 859 | 926 | 994 | 1 062 | 1 130 | 1 199 | 1 268 | 1 338 | 1 407 |
| 75. Торф | — | 75a Кусковой | $I_{г}^{0}$ | 1 804 | 1 974 | 2 147 | 2 320 | 2 495 | 2 672 | 2 849 | 3 029 | 3 209 | 3 389 | 3 570 |
| | | | $I_{в}^{0}$ | 1 261 | 1 376 | 1 493 | 1 610 | 1 728 | 1 846 | 1 964 | 2 084 | 2 204 | 2 326 | 2 446 |
| 76. " | — | 76a Фрезерный | $I_{г}^{0}$ | 1 610 | 1 762 | 1 916 | 2 072 | 2 239 | 2 387 | 2 547 | 2 708 | 2 870 | 3 032 | 3 194 |
| | | | $I_{в}^{0}$ | 1 050 | 1 146 | 1 243 | 1 341 | 1 439 | 1 537 | 1 636 | 1 736 | 1 836 | 1 937 | 2 037 |
| 77. Дрова | — | — | $I_{г}^{0}$ | 1 751 | 1 916 | 2 084 | 2 253 | 2 423 | 2 595 | 2 768 | 2 942 | 3 117 | 3 293 | 3 469 |
| | | | $I_{в}^{0}$ | 1 178 | 1 286 | 1 395 | 1 504 | 1 614 | 1 725 | 1 836 | 1 948 | 2 060 | 2 173 | 2 235 |
| 78. Коксовая мелочь | — | — | $I_{г}^{0}$ | 2 916 | 3 187 | 3 463 | 3 738 | 4 016 | 4 297 | 4 578 | 4 861 | 5 145 | 5 429 | 5 715 |
| | | | $I_{в}^{0}$ | 2 476 | 2 703 | 2 931 | 3 161 | 3 393 | 3 625 | 3 857 | 4 093 | 4 328 | 4 567 | 4 802 |
| 79. Мазут | — | 79a Малосернистый | $I_{г}^{0}$ | 5 012 | 5 479 | 5 954 | 6 429 | 6 903 | 7 393 | 7 878 | 8 368 | 8 859 | 9 350 | 9 844 |
| | | | $I_{в}^{0}$ | 4 304 | 4 699 | 5 097 | 5 496 | 5 899 | 6 302 | 6 706 | 7 116 | 7 526 | 7 941 | 8 351 |
| 80. " | — | 80a Высокосернистый | $I_{г}^{0}$ | 4 946 | 5 407 | 5 875 | 6 344 | 6 817 | 7 294 | 7 774 | 8 257 | 8 741 | 9 225 | 9 713 |
| | | | $I_{в}^{0}$ | 4 249 | 4 639 | 5 031 | 5 426 | 5 823 | 6 222 | 6 620 | 7 025 | 7 429 | 7 839 | 8 243 |

* During calculation $I_{г}^{0}$ for tne schists the ccefficient of the expansion of carbonates $k$ was taken equal tc cne.

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(1) ПРИСОСЫ ВОЗДУХА В ГАЗОХОДАХ КОТЕЛЬНЫХ АГРЕГАТОВ | РН 4-06

| (2) Газоход | | | (3) Величина присоса |
|---|---|---|---|
| (4) Топочная камера | (5) Камерные топки при обычной обмуровке и отсутствии гидравлического уплотнения шлаковой шахты, а также слоевые топки | | 0,1 |
| | (6) Камерные топки при подвесной обмуровке и гидравлическом уплотнении шлаковой шахты, камеры с жидким шлакоудалением и камеры газо-мазутных топок | | 0,05 |
| (7) Газоходы котельных пучков | (8) Фестон, ширмовый перегреватель и первый котельный пучок котлов большой и средней производительности | | 0 |
| | (9) Первый котельный пучок котлов $D \leq 12$ $m/час$ | | 0,05 |
| (10) | Второй и третий котельные пучки котлов большой и средней производительности | | 0,05 |
| (11) | Второй котельный пучок котлов $D < 12$ $m/час$ | | 0,1 |
| (12) Газоход перегревателя | | | 0,05 |
| (13) Газоход вторичного перегревателя или части первичного, расположенной в конвективной шахте | | | 0,03 |
| (14) Газоход переходной зоны | | | 0,03 |
| (15) Газоходы экономайзеров | (16) Стальные змеевиковые экономайзеры котлов большой и средней производительности | (17) При одноступенчатом выполнении | 0,03 |
| | | (18) При двухступенчатом выполнении на каждую ступень | 0,02 |
| (19) | Стальные змеевиковые экономайзеры котлов $D \leq 12$ $m/час$ | | 0,08 |
| (20) | Чугунные экономайзеры | | 0,1 |
| (21) Воздухоподогреватели | (22) Трубчатые | (23) При одноступенчатом выполнении | 0,05 |
| | | При двухступенчатом выполнении на каждую ступень (24) | 0,05 |
| | (25) Пластинчатые | При одноступенчатом выполнении (23) | 0,07 |
| | | При двухступенчатом выполнении на каждую ступень (24) | 0,07 |
| | Чугунные (26) | (26a) Из ребристых труб, на каждую ступень | 0,1 |
| | | Из ребристых плит (26b) | 0,2 |
| (28) | Регенеративные (27) | | 0,2 |
| Золоуловители | Электрофильтры (29) | | 0,1 |
| (30) | Циклонные золоуловители или скрубберы | | 0,05 |
| (31) | Встроенный жалюзийный золоуловитель | | 0,05 |
| (32) Газоходы (на 10 пог. м) | Стальные (33) | | 0,01 |
| | Кирпичные борова (34) | | 0,05 |

Key: (1). Suctions of air in the flues of boiler aggregates/units. (2). Flue. (3). Value of suction. (4). Furnace chamber/camera. (5). Chamber furnaces when common bricking and hydraulic seal of slag mine/shaft is absent,, and also layer heatings. (6). Chamber furnaces with suspension bricking and hydraulic seal of slag mine/shaft, chamber/camera with liquid slag removal and chamber/camera of gas-oil heatings. (7). Flues of boiler bundles. (8). Scallop, screen superheater and first boiler bundle of boilers of large and average efficiency. (9). First boiler bundle of boilers D≤12 t/h. (10). Second and third boiler bundles of boilers of large and average efficiency. (11). By the second boiler bundle of boilers D≤12 t/h. (12). Flue of superheater. (13). Flue of secondary superheater or part of primary, arranged/located in convective mine/shaft. (14). Flue of transient zone. (15). Flues of economizers. (16). Steel continuous-tubes economizer of boilers of large and average efficiency. (17). With single-stage execution. (18). With two-stage execution to each step/stage. (19). Steel continuous-tubes economizer of boilers D≤12 t/h. (20). Cast iron economizers. (21). air preheaters. (22). Tubular. (23). With single-stage execution. (24). With two-stage execution to each step/stage. (25). Lamellar. (26). Cast iron. (26a). From the finned tubes, to each step/stage. (26b). From the ribbed slabs. (27). Regenerative. (28). Ash catchers. (29). Electric filters. (30). Cyclonic ash catchers or scrubbers. (31). Built-in louvered ash catcher. (32). gas conduits (to 10 running m). (33). Steel. (34). Brick flues.

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Calculation of a quantity of air, which emerges from the air preheater. RN 4-07.

The ratio of a quantity of air at the output/yield from the air preheater to theoretically necessary is determined from the formula

$$\beta''_{вп} = \alpha_т - \Delta\alpha_т - \Delta\alpha_{пл.у},$$

where $\alpha_т$ - excess air ratio in the heating, determined in RN 5-02-5-05;

$\Delta\alpha_т$ - suction of air in the heating, determined on RN 4-06;

$\Delta\alpha_{пл.у}$ - value of the suction of air in the dust-preparatory installation, referred to the theoretically necessary quantity of the air; in general it is designed in accordance with indications p. 4-17.

In the absence of the calculation of dust preparation values $\Delta\alpha_{пл.у}$ are accepted on the following table.

Average/mean values $\Delta\tau_{пл.у}$ for different systems of pulverized coal preparation.

| (a) Характеристика пылесистемы | $\Delta\alpha_{пл.у}$ (b) Котлы D<75 т/час | (b) Котлы D>75 т/час |
|---|---|---|
| (c) I. Системы с шаровыми барабанными мельницами, индивидуальная схема с пылевым бункером[1] | | |
| 1. При сушке горячим воздухом из первой и второй ступеней воздухоподогревателя или смесью горячего воздуха с рециркулирующим агентом. Топливо — каменные угли . . . . . . . | 0,08 | 0,06 |
| 2. То же, что п. 1, топливо — бурые угли умеренной влажности | 0,12 | 0,10 |
| 3. При сушке смесью топочных газов с горячим воздухом, а также пылесистема с предвключенной трубой-сушилкой при сушке двумя сушильными потоками, состоящими из смеси топочных газов и горячего воздуха . . . . . . . . . . . . | 0,16 | 0,08 |
| (d) II. Пылесистемы с шахтными мельницами | | |
| (e) *а) При сжигании бурых углей* | | |
| 4. Сушка горячим воздухом . . . . . . . . . . . . . . . . . | 0,03 | |
| 5. Сушка смесью горячего воздуха и топочных газов . . . . . . | 0,05 | |
| (f) *б) При сжигании каменных углей* | | |
| 6. Сушка горячим воздухом . . . . . . . . . . . . . . . . . | 0,02 | |
| 7. Сушка горячим воздухом с присадкой холодного воздуха . . | 0,04[2] | |
| 8. III. Среднеходные мельницы . . . . . . . . . . | 0,03 | |
| 9. IV. Пневмомельницы . . . . . . . . . . . . . . . | 0,08 | |
| 10. V. Быстроходные бильные мельницы . . . . | 0,05 | |

Key: (a). Characteristic of dust system. (b). Boilers D<75 t/h. (c). I. Systems with the spherical rattlers, individual diagram with the dust hopper [1].

FOOTNOTE [1] In the diagram of pulverized coal preparation with the straight/direct injection of value $\Delta\alpha_{пл.у}$ are multiplied by coefficient 0.8. ENDFOOTNOTE.

(1). With drying by hot air from first and secondary air heaters or

by mixture of hot air from recirculating agent. Fuel/propellant - coals. (2). The same as p. 1, fuel/propellant - brown coal of moderate humidity. (3). With drying by mixture of flue gas from hot air, and also dust-system with series-connected duct- desiccator with drying by two drying flows, which consist of mixture of flue gas and hot air. (d). II. Dust-systems with the unit type mills. (e). During combustion of brown coal. (4). Drying by hot air. (5). Drying by mixture of hot air and flue gas. (f). During combustion of coals. (6). Drying by hot air. (7). Drying by hot air with additive of cold air. (8). III. medium-speed mills. (9). IV. Pneumo-mills. (10). V. High-speed hammer mills.

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FOOTNOTE [2]. The value of the additive of cold air is calculated separately and it is adjoined to $\alpha_{m.p.}$ ENDFOOTNOTE.

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The heat balance of boiler aggregate/unit. RN 5-01.

1. Available heat of fuel/propellant:

$$Q_{р}^{р}=Q_{н}^{р}+Q_{в.вн}+i_{тл}+Q_{ф}-Q_{к} \quad \text{kcal/kg;}$$

for gases of different fuel/propellant

$$Q_{р}^{с}=Q_{н}^{с}+Q_{в.вн}+i_{тл}+Q_{ф} \quad \text{kcal/nm}^3.$$

$Q_{в.вн}$ - heat, introduced with the entering the boiler aggregate/unit air during preheating of the latter out of the aggregate/unit, kcal/kg or kcal/nm³;

$i_{тл}$ - physical heat of fuel/propellant, kcal/kg or kcal/nm³; in the absence of the extraneous preheating of fuel/propellant value $i_{тл}$ is considered only with

$$W^{р}>\frac{Q_{н}^{р}}{150}\%;$$

$Q_{ф}$ - the heat, introduced into the aggregate/unit by steam which proceeds with blasting and pulverization kcal/kg.

$Q_{к}$ - the heat, spent on decomposition of carbonates, kcal/kg.

2. Heat loss with stack gases

$$q_2 = \frac{(I_{yx} - a_{yx} I^0_{x.в})(100 - q_4)}{Q^p_p} \%.$$

$I_{yx}$ - enthalpy of stack gases, kcal/kg or kcal/nm³;

$I^0_{x.в}$ - enthalpy of theoretically necessary quantity of air, kcal/kg or kcal/nm³; temperature of cold air takes as equal to 30°C.

3. Heat loss from chemical incompleteness of combustion $q_3$ is determined on RN 5-02-5-05.

4. Heat loss from mechanical incompleteness of combustion $q_4$ is determined on RN 5-02-5-05 or p. 5-09.

5. Heat loss from external cooling $q_5$ for stationary boiler aggregates/units is accepted on graph/curve.


The rated steam capacity of boiler -

Key: (1). Strictly boiler without the tail surfaces. (2). Boiler aggregate/unit with tail surfaces. (3). t/h.

With the loads, which differ from nominal it is more than by 25o/o, value $q_5$ is counted over according to the formula

$$q_5 = q_5^{ном} \frac{D_{ном}}{D} \%.$$

Coefficient of the retention/preservation/maintaining the heat

$$\varphi = 1 - \frac{q_5}{100}.$$

6. Loss with physical heat of slags

$$q_{6\,шл} = \frac{a_{шл}\,(ct)_{шл}\,A^p}{Q_p^p} \%,$$

where $a_{шл} \approx 1 - a_{ун}$ is determined on BN 4-01;

$(ct)_{шл}$ - enthalpy of ash and slag, determined on BN 4-04, kcal/kg.

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The temperature of slags with the dry slag removal takes as the equal to 600°C, and with the liquid - temperature of the fluid state of ash plus of 100°C.

During the chamber combustion with dry slag removal $q_{6\,шл}$ it is considered only with

$$A^{p} \geq \frac{Q_{н}^{p}}{100}\,\%.$$

During the layer combustion of schists instead of $A^{p}$ is substituted value $A^{p}+0{,}3\,(CO_2)_{к}^{p}\,\%$.

7. Heat loss to cooling of not connected with circulation of boiler panels and beams/gullies

$$q_{6\,охл}=\frac{Q_{6\,охл}}{Q_{р}^{p}}\approx\frac{\left(\frac{Q}{H}\right)_{охл} H_{охл}}{Q_{к.а}}\,\%.$$

$\left(\frac{Q}{H}\right)_{охл}$ - heat absorption to 1 m² of beam-receiving surface of beams/gullies, taken usually $\left(\frac{Q}{H}\right)_{охл}=100\,000$ kcal/m²h;

$H_{охл}$ - beam-receiving surface of beams/gullies and panels, m²; for latter is considered only lateral surface, converted into heating.

8. Total heat loss in boiler aggregate/unit

$$\Sigma q=q_2+q_3+q_4+q_5+q_{6\,шл}+q_{6\,охл}\,\%.$$

Efficiency (efficiercy) of boiler aggregate/unit (gross weight)

$$\eta_{\text{к.а}} = 100 - \Sigma q\%.$$

9. Total quantity of heat, usefully returned in boiler aggregate/unit,

$$Q_{\text{к.а}} = D_{\text{пе}} (i_{\text{п.п}} - i_{\text{п.в}}) + D_{\text{н.пе}} (i_{\text{н.п}} - i_{\text{п.в}}) + \\ + D_{\text{пр}} (i_{\text{кип}} - i_{\text{п.в}}) + D_{\text{вт.пе}} (i''_{\text{вт.пе}} - i'_{\text{вт.пе}}) + \\ + Q_{\text{отд}} \text{ ккал/час, (1)}$$

Key: (1). kcal/h.

$D_{\text{пе}}$ - quantity of manufactured superheated steam, kg/h;

$i_{\text{п.п}}$ - enthalpy of the superheated steam, kcal/kg;

$i_{\text{п.в}}$ - enthalpy of feed water on the entrance into the aggregate/unit, kcal/kg;

$D_{\text{н.п}}$ - quantity of the saturated steam, returned besides the superheater, kg/h;

$D_{\text{пр}}$ - expenditure oxen for the blasting of the boiler; is considered with the value of blasting of more than 2o/c, kg/h;

$i_{\text{кип}}$ - enthalpy of water at a boiling point, kcal/kg;

$D_{\text{вт.п}}$ - expenditure/consumption of steam through the secondary of superheater, kg/h;

$i'_{\text{вт.пе}}$ and $i''_{\text{вт.пе}}$ - enthalpy of the secondary steam at the entrance into the superheater and on leaving from it, kcal/kg;

$Q_{\text{отб}}$ - heat absorption of the water or air, preheated in the boiler aggregate/unit and loosened to the side, kcal/h.

10. Consumption of fuel, supplied to heating,

$$B=\frac{Q_{\text{к.а}}}{Q^{р}_{р}\eta_{\text{к.а}}}\cdot 100 \quad \text{kg/h}.$$

Calculated consumption of fuel

$$B_{р}=B\left(1-\frac{q_4}{100}\right) \quad \text{kg/h}.$$

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Design characteristics of chamber furnaces with the dry slag removal [1]. RN 5-02.

FOOTNOTE [1]. The led in RN characteristics of pulverized coal and mine- mill heatings are given for installations with the closed diagram of dust preparation. For guaranteeing the characteristics indicated the fineness of dust must correspond to the recommendations of standards of pulverized coal preparation.

In the extended diagram of pulverized coal preparation are accepted the following characteristics:

a) the excess air ratio in the heating: for the Volga schists in milled peat $\alpha_m = 1.2$; for brown coal $\alpha_m = 1,15$;

b) value $q_3$ - the same as for the closed diagram;

c) value $q_4$ in size/dimension of 50o/o from values of $q_4$ for the closed diagram.

| (1) Тип топки | (2) Наименование топлива | (3) Коэффициент избытка воздуха в топке $\alpha_m$ | (4) Допустимое по условиям горения теплонапряжение топочного объема $BQ^р_н/V_т\cdot10^3$, ккал/м³час | (5) Потери тепла (6) от химической неполноты сгорания $q_3$, % | (7) от механической неполноты сгорания[2] $q_4$, % (8) Котлы $D>50$ т/час | (8) Котлы $D<50$ т/час |
|---|---|---|---|---|---|---|
| (9) Пылеугольные | (10) Антрацитовый штыб* | 1,25 | 125 | 0 | 4 | 5[3] |
| | (11) Полуантрациты* | 1,25 | 140 | 0 | 3 | 5[3] |
| | (12) Тощие угли | 1,25 | 160 | 0 | 2 | 3[3] |
| | (13) Каменные угли, $V^г\leq25\%$ | 1,2 | 160 | 0 | 2 | 3 |
| | (13) Каменные угли, $V^г>25\%$ | 1,2 | 160 | 0,5 | 1,5 | 2.5 |
| | (14) Отходы углеобогащения, $V^г>25\%$ | 1,2 | 150 | 0,5 | 2,5[4] | 3,5[4] |
| | (15) Бурые угли | 1,2 | 200 | 0,5 | 0,5 | 1 |
| (16) Шахтно-мельничные | (13) Каменные угли, $V^г>30\%$ ($k_{ло}\geq1,2$) | 1,25 | 130 | 0,5 | 4 | 6 |
| | (15) Бурые угли | 1,25 | 150 | 0,5 | 1 | 2 |
| | (17) Сланцы гдовские и эстонские | 1,25 | 120 | 0,5 | 1 | 1,5 |
| | (18) Сланцы волжские | 1,25 | 140 | 1 | 2 | 3 |
| | (19) Фрезерный торф | 1,25 | 150 | 1 | 1 | 2 |
| (20) Пневматические ЦКТИ системы Шершнева | (19) Фрезерный торф $W^р<55\%$ | 1,25 | 120 | 0,5 | 2 | 3[5] |
| | (15) Бурые угли, $W^р=15\div30\%$ | 1,3 | 150 | 1[6] | — | 4[6] |
| (21) Экранированные | (22) Мазут, природный и нефтяной газы | 1,15[7] | 250[8] | 1,5[9] | — | |
| (23) Неэкранированные | (22) Мазут, природный и нефтяной газы | 1,15[10] | 200 | 1[9] | — | |
| (24) Факельное сжигание | (25) Доменный газ | 1,15 | 200 | 3 | — | |
| (26) Беспламенное сжигание (для котлов $D\leq20$ т/час) | (25) Доменный газ | 1,15 | 750 | 1 | — | |

Key: (1). Type of heating. (2). Designation of fuel/propellant. (3). Excess air ratio in heating. (4). Permitted according to combustion conditions thermal stress of furnace cavity $BQ^p_н/V_т\cdot10^3$, kcal/m³h. (5). Heat losses. (6). from chemical incompleteness of combustion $q_3$, o/c. (7). from mechanical incompleteness of combustion [2] $q_4$, o/o.

FOOTNOTE [2]. During planning of boilers D>50 t/h with the increased

against those indicated in the table thermal stresses of furnace cavity (but not more than tc 15c/c) or fcr the increased against the tabular values ash content of the fuel/propellant of value $q_4$ are accepted the same as fcr boilers D≤50 t/h. ENDFOOTNOTE.

(8). Boilers D>50 t/h. (9). Pulverized ccal. (10). Anthracite fines*.

FOOTNOTE *. Values $q_4$ are given fcr the heatings with the supply tc dust by hot air and inclined-horizontal hearth for the liquid slag removal (also with the heated funnels); in the heatings with the cold funnels $q_4$ by 1o/o it is higher. ENDFOOTNOTE.

(11). Carbonaceous coal*. (12). Lean coal. (13). Coals. (14). By-product coal. (15). Brown ccal. (16). Mine-mill. (17). Schists Gdovskiy and Estonian). (18). Schists (Vclga. (19). Milling peat. (20). Pneumatic TsKTI system cf Shershnev. (21). Shielded. (22). Petroleum residue, natural and petroleum gases. (23). Not shielded. (24). Torch combustion. (25). Blast-furnace gas. (26). Flameless combustion (for boilers D≤20 t/h).

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FOOTNOTE [3]. For boilers D>35 t/h; with D<35 t/h of value $q_4$ they are accepted to 2o/o above.

[4]. For by-product coal from $V^{r} < 25\%$ value of $q_4$ are accepted to C.5o/c above.

[5]. For boilers D≥20 t/h; with D<20 t/h value $q_4$ it increases by 1-2o/o and $q_3$ by 1-20o/c. With D<6.5 t/h is accepted $\alpha_m = 1.3$ and $BQ^{p}_{n}/V_m < 300 \cdot 10^{3}$ kcal/m³h.

[6]. For boilers D≤6.5 t/h.

[7]. For automated boilers with the presence cf pressure regulator of gas before each boiler is admissible decrease $\alpha_m$ tc 1.1.

[8]. For natural gas with $Q^{p}_{n} > 9000$ kcal/nm³ of value $q_3$ are accepted to 0.5o/o above.

[9]. During increased pressure heads of blasting and use/application of special registers of thermal stress of heatings can be increased several times without reduction in efficiency/ccst-effectiveness of burning process.

[10]. In the unshielded heatings is admissible fcr the protection of bricking the increase $\alpha_m$ EBDFCCTNCTE.

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Design characteristics cf layer mechanical and semimechanical heatings [1]. RN 5-03.

FOOTNOTE [1]. Characteristics relate to crushed series brown and coals and anthracite with the content cf trifle 0-6 mm not more than 55o/c and by the maximum size cr pieces 30-40 mm. The combustion of fuel/propellant with the content cf trifle cf more than 55o/c in the layer heatings is not recommended, since in this case noticeably is raised $q_4$, especially fcr ARSh. ENDFOOTNOTE.

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| (1) Наименование величины | (2) Обозначение | (3) Размерность | (4) Топки с цепной решеткой: (5) Бурые угли типа челябинских, $A^n = 6,5$ | (6) Неспекающиеся каменные угли типа Д и Г, $A^n = 4$ | (7) Слабоспекающиеся каменные угли типа СС, $A^n = 2$ | (8) Антрациты: (9) АС и АМ, $A^n = 2$ | (9) АРШ и АСШ, $A^n = 3$ | (10) Шахтно-цепная топка: (10a) Торф кусковой, $W^p = 45 \div 50\%$, $A^n = 3$ | (11) Топки с цепной решеткой и забросом топлива на слой: (12) Бурые угли: (13) типа подмосковных, $A^n = 10$ | (14) типа челябинских, $A^n = 6,5$ | (15) Каменные угли с $V^г > 25\%$, $A^n = 4$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| (29) Видимое теплонапряжение зеркала горения | $\frac{BQ_н^p}{K} \cdot 10^{-3}$ | (30) $\frac{ккал}{м^2 \cdot час}$ | 900 | 1 000 | 900 | 1 000 | 700÷800 | 1500÷1900[4] | 900÷1 200[5] | 900÷1 400[6] | 900÷1 400[6] |
| (31) Видимое теплонапряжение топочного объема[2] | $\frac{BQ_н^p}{V_m} \cdot 10^{-3}$ | (32) $\frac{ккал}{м^3\ час}$ | ← 200÷250 → | | | 250÷300 | ← 200÷250 | | | | |
| (33) Коэффициент избытка воздуха в топке | $\alpha_m$ | — | 1,3 | 1,3 | 1,3 | 1,3 | 1,5 | 1,3 | 1,3 | 1,3 | 1,3 |
| (34) Потеря от химической неполноты сгорания[3] | $q_3$ | % | 1 | 1 | 1 | 0 | 0 | 1 | 0,5 | 0,5 | 0,5 |
| (35) Потеря от механической неполноты сгорания | $q_4$ | % | 5 | 6 | 5 | 7 | 14 | 2 | 9 | 6 | 6 |
| (36) Содержание горючих в шлаке и провале | $Г_{шл+пр}$ | % | 6 | 12 | 20 | 20 | 25 | — | 7 | 6 | 10 |
| (37) Содержание горючих в уносе | $Г_{ун}$ | % | 20 | 30 | 35 | 50 | 55 | — | 20 | 20 | 30 |
| (38) Доля золы топлива в шлаке и провале | $a_{шл+пр}$ | — | 0,8 | 0,8 | 0,8 | 0,75 | 0,7 | — | 0,75 | 0,75 | 0,75 |
| (39) Доля золы топлива в уносе | $a_{ун}$ | — | 0,2 | 0,2 | 0,2 | 0,25 | 0,3 | — | 0,25 | 0,25 | 0,25 |
| (40) Давление воздуха под решеткой | $p_в$ | (42) мм вод. ст. | 80 | 80 | 80 | 100 | 100 | 80 | 80 | 80 | 80 |
| (41) Температура дутьевого воздуха[7] | $t_в$ | °C | 250 | 25÷200 | 25÷200 | 25÷150 | 25÷150 | 250 | 250 | 25÷250 | 25÷200 |

| (16) Топки с шурующей планкой | | | (17) Топки с забрасывателями и неподвижным слоем | | | | (19) Топки с наклонно-переталкивающими решетками | | (22) Шахтные топки | (24) Скоростные топки | | (27) Топка с наклонной решеткой (финская) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (12) Бурые угли | | (15) | (12) Бурые угли | | (15) | (18) | (20) | (21) | (23) | (25) | (26) | (28) |
| (13) типа подмосковных, $A^п = 10$ | (14) типа челябинских, $A^п = 6,5$ | Каменные угли с $V^г > 25\%$, $A^п = 4$ | (13) типа подмосковных, $A^п = 10$ | (14) типа челябинских, $A^п = 6,5$ | Каменные угли с $V^г > 25\%$, $A^п = 4$ | Антрациты АРШ, $A^п = 3$ | Бурые угли с $W^р < 40\%$, $A^п = 6,5 \div 10$ | Эстонские и гдовские сланцы, $A^п = 25$ | Торф, $W^р = 40\%$, $A^с = 10\%$ | Рубленая щепа, $W^р = 40 \div 50\%$ | Дробленые отходы и опилки, $W^р = 40 \div 50\%$ | Древесные отходы и опилки, $W^р = 50\%$ |
| 700÷800 | 800÷900 | 900 | 800÷900 | 900 | 900 | 800÷900 | 700 | 800 | 1 100 | 5 000÷8 000* | 2 000÷4 000* | 500 |
| 200÷250 → | | | | | | | | 200 | 200÷250 | 300÷400 | 300÷400 | 200÷250 |
| 1,4 | 1,4 | 1,4 | 1,4 | 1,4 | 1,4 | 1,6 | 1,3 | 1,4 | 1,4 | 1,2 | 1,3 | 1,4 |
| 1 | 1 | 2 | 1 | 1 | 1 | 0,5 | 1 | 3 | 2 | 3 | 4 | 4 |
| 9 | 6 | 7 | 11 | 7 | 7 | 18 | 5÷7 | 3 | 2 | | | |
| 6 | 6 | 15 | 10 | 10 | 15 | 25 | 5 | — | — | — | — | — |
| 20 | 20 | 30 | 20 | 20 | 30 | 65 | 20 | — | — | — | — | — |
| 0,75 | 0,75 | 0,8 | 0,75 | 0,75 | 0,75 | 0,7 | 0,8 | — | — | — | — | — |
| 0,25 | 0,25 | 0,2 | 0,25 | 0,25 | 0,25 | 0,3 | 0,2 | — | — | — | — | — |
| 100 | 100 | 100 | 60 | 60 | 60 | 100 | 60 | 60 | 60 | 70 | 100 | 80 |
| 25÷200 | 25÷200 | 25[3] | 25÷200 | 25÷200 | 25[3] | 25 | 200 | 200 | 25÷200 | 25÷250 | 25÷250 | 25÷200 |

Key: (1). Designation cf values. (2). Designaticn. (3). Cimensionality. (4). Heatings with chain grate. (5). Brcwn ccal of type of Chelyatinsk cnes. (6). Nonsintering ccals of type D and G. (7). Mildly sintered ccals of type. (8). Anthracite. (9). and. (10). Mine-chain/catenary heating. (10a). Peat of cake. (11). Heatings with chain grate and throw/excess/cvershcot of fuel/propellant to layer.

(12). Brown coal. (13). type of Moscow ones. (14). type of Chelyabinsk ones. (15). Coals s. (16). Heatings with poking bar/plate. (17). Heatings with spreaders and fixed bed. (18). Anthracite. (19). Heatings inclined-foil shaking grates. (20). Brown coal s. (21). Estonian and Gdovskiy schists. (22). Mine heatings. (23). Peat. (24). High-speed/high-velocity are thin. (25). Chopped chips. (26). Crushed siftings and turnings. (27). Heating with inclined grate (Finnish). (28). Wood withdrawals/departures and filings. (29). Seen thermal stress of mirror of combustion. (30). kcal/m²h. (31). Seen thermal stress of furnace cavity [2].

FOOTNOTE [2]. When afterburner is present, computed value of the thermal stress of furnace cavity can be somewhat increased. ENDFOOTNOTE.

(32). kcal/m³h. (33). Excess air ratio in heating. (34). Loss from chemical incompleteness of combustion [3].

FOOTNOTE [3]. For the heatings with the moving layer the values of loss $q_3$ are given in the presence of secondary blasting. ENDFOOTNOTE.

(35). Loss from mechanical incompleteness of combustion. (36). Content of fuels in slag and failure/dip/trough. (37). Content of fuels in escape. (38). Share of ash of fuel/propellant in slag and

failure/dip/trough. (39). Share of ash of fuel/propellant in escape. (40). Air pressure under grate. (41). Temperature of blast air [7].

FOOTNOTE [7]. Indication about the temperature of blast air, equal to 25°C, is given for those cases when preheating air is undesirable on conditions of the work of grate bar fabric. ENDFOOTNOTE.

(42). mm $H_2O$.

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FOOTNOTE [4]. Smaller values - for the boilers with D<35 t/h.

[5]. Smaller values - for boilers with D<20 t/h.

[6]. Smaller values for boilers with D<10 t/h. Reference area of the mirror of combustion is defined as product from the distance from the hearth of mine/shaft to the narrowing to its width.

[8]. For cannel coal is allowed/assumed preheating air to 150°C.

[9]. It is accepted tentatively. ENDFOOTNOTE.

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Design characteristics cf layer heatings with the rigid lattice and the manual throw/excess/cvershcct cf fuel/prcpellant. RN 5-04.

| (1) Наименование величин | (2) Обозначение | (3) Размерность | (4) Бурые угли | | | (5) Рядовые каменные угли | | (6) Антрациты | |
|---|---|---|---|---|---|---|---|---|---|
| | | | (7) рядовые с умеренной зольностью и влажностью (типа челябинских), $A^п=6,5$ | (8) рядовые влажные многозольные (типа подмосковных), $A^п=10$ | (9) сортированные (типа подмосковных), $A^п=8$ | (10) с $V^г>25\%$, $A^п=4$ | (11) тощие, $A^п=2,5$ | (12) сортированные АС и АМ, $A^п=2$ | АРШ, $A^п=3$ |
| (13) Видимое напряжение зеркала горения | $\frac{BQ^р_н}{R}\cdot 10^{-3}$ | (14) $\frac{ккал}{м^2 час}$ | 800 | 700 | 900 | 800 | 700 | 900 | 800 |
| (15) Допустимое теплонапряжение топочного объема | $\frac{BQ^р_н}{V_т}\cdot 10^{-3}$ | (16) $\frac{ккал}{м^3 час}$ | ← | | | 250÷300 | | | → |
| (17) Коэффициент избытка воздуха в топке | $a_т$ | — | 1,4 | 1,4 | 1,35 | 1,4 | 1,4 | 1,3 | 1,5 |
| (18) Потеря от химической неполноты сгорания | $q_3$ | % | 2 | 3 | 2 | 5 | 3 | 2 | 2 |
| (19) Потеря от механической неполноты сгорания | $q_4$ | % | 7 | 11 | 8 | 7 | 6 | 7 | 14 |
| (20) Содержание горючих в шлаке и провале | $Г_{шл+пр}$ | % | 12 | 12 | 10 | 15 | 10 | 20 | 20 |
| (21) Содержание горючих в уносе | $Г_{ун}$ | % | 15 | 15 | 15 | 25 | 45 | 50 | 55 |
| (22) Доля золы топлива в шлаке и провале | $a_{шл+пр}$ | — | 0,75 | 0,75 | 0,8 | 0,8 | 0,7 | 0,7 | 0,65 |
| (23) Доля золы топлива в уносе | $a_{ун}$ | — | 0,25 | 0,25 | 0,2 | 0,2 | 0,3 | 0,3 | 0,35 |
| (24) Давление воздуха под решеткой | $p_в$ | (25) мм вод. ст. | 100 | 100 | 100 | 90 | 80 | 100 | 100 |

Key: (1). Designation cf values. (2). Designaticn. (3). Dimensionality. (4). Brcwn ccal. (5). Run-of-mine ccals. (6). Anthracite. (7). Privates witn mcderate ash ccntent and humidity (cf type of Chelyabinsk cnes). (8). series humid ash-rich (type cf Moscow

ones). (9). sorted (type Moscow region). (10). s. (11). lean. (12). sorted AS and AM. (13). Visible stress/voltage of mirror of combustion. (14). kcal/$m^2$h. (15). Permitted thermal stress of furnace cavity. (16). kcal/$m^3$h. (17). Excess air ratio in heating. (18). Loss from chemical incompleteness of combustion [1].

FOOTNOTE [1]. Taking into account the soot formation. ENDFOOTNOTE.

(19). Loss from mechanical incompleteness of combustion. (20). Content of fuels in slag and failure/dip/trough. (21). Content of fuels in escape. (22). Share of ash of fuel/propellant in slag and failure/dip/trough. (23). Share of ash of fuel/propellant in escape. (24). Air pressure under grate. (25). mm $H_2O$.

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Design characteristics of liquid-bath furnaces[1]. RN 5-05.

FOOTNOTE [1]. In connection with the limitedness of data on the liquid-bath furnaces given in present RN data should be considered as the tentative. For the heatings with an inclined-horizontal hearth for the liquid slag removal (with the heated funnels) the design characteristics are received by the same as for the heatings with the dry slag removal, with exception $a_{yn}=0.8+85$. ENDFOOTNOTE.

The magnitude of losses of heat from the chemical incompleteness of combustion $q_3$ for the single-chamber heatings is received by the same as for the heatings with the dry slag removal, on RN 5-02. For two-and the multichamber heatings and cyclonic type heatings $q_3=0$.

Magnitude of losses from the mechanical incompleteness of combustion $q_4$ is decreased in comparison with that recommended for the heatings with the dry slag removal proportional to a change of the share of ash in the escape - RN 4-01.

Remaining characteristics are accepted on the table.

| (1) Тип топки | (2) Коэффициент избытка воздуха в конце топки $\alpha_m$ [2] | (3) Соотношение между теплонапряжениями объема топок с жидким и сухим шлакоудалением [1] | (4) Доля золы топлива, уносимая газами, $a_{ун}$ |
|---|---|---|---|
| (5) Однокамерные топки . . . . . . . . . . . . . . | 1,15÷1,2 | 1,2 | 0,6÷0,7 |
| (6) В том числе ошипованная зона экранов . . | | 5,0 | |
| (7) Двухкамерные топки . . . . . . . . . . . . . . | | 1,3 | 0,4÷0,5 |
| (8) В том числе первые камеры . . . . . . . . . . | 1,1—1,15[3] | 5,0 | — |
| Топки с высоким шлакоудалением . . . . . . (9) | | 1,5 | 0,1÷0,15 |
| (12) В том числе: (11) а) предтопки топок ВТИ ($L/D \approx 5,0$) | 1,1[2] | (10) Размеры выбираются по тепловому напряжению сечения, равному (15÷16) $10^6$ *ккал/м²час* | |
| (13) б) циклонные предтопки ($L/D \approx 1,25$) | | (14) То же по тепловому напряжению сечения, равному (12÷13) $10^6$ *ккал/м²час* | |

Key: (1). Type of heating. (2). Excess air ratic at the end cf heating. (3). Relaticnship/ratic between thermal stresses of volume of heatings with liquid and dry slag remcval[1].

FOOTNOTE [1]. The thermal stresses of the volume of heatings with the dry slag removal in depending on the type of fuel/propellant are accepted on RN 5-02. ENDFOOTNOTE.

(4). Share of ash of fuel/propellant, taken away by gases. (5). Single-chamber heatings. (6). Amcng other things pinned zcne of shields. (7). Two-chamber heatings. (8). Amcng cther things first chambers/cameras. (9). Heatings with high slag removal. (10).

Sizes/dimensions are selected by thermal stresses of section/cut, equal to (15-16) $10^6$ kcal/$m^2$h. (11). precombustion chambers of heatings. (12). Among other things. (13). cyclonic precombustion chambers. (14). Then on thermal stresses of section/cut, equal to (12-13) $10^6$ kcal/$m^2$h.

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FOOTNOTE [2]. The excess air ratio at the output/yield from the heating (from the second chamber/camera or cooling chamber) is determined taking into account the suction in these chambers/cameras. The value of suction is determined on BN 4-06.

*. For ASh - upper limit. ENDFOOTNOTE.

The calculation of heat exchange in the heating. RN 6-01.

The temperature of gases at the output/yield from the heating is determined on nomogram I.

Note. The pneumatic heatings of TsKTI the system of Shershnev with the shielded ejector funnels and anthracitic layer heatings are designed not on nomogram I, but according to formula (6-04).

For using nomogram I is calculated value

$$\frac{B_p Q_m}{\zeta H_A} \text{ kcal/m}^2\text{h},$$

$B_p$ - a calculated consumption of fuel, kg/h or $nm^3$/h;

$Q_m$ - useful heat release in the heating, kcal/kg or kcal/$nm^3$:

$$Q_m = Q_p^p \frac{100 - q_3 - q_6}{100} + Q_e - Q_{e.vnsh} + r I_{g.otb} \text{ ккал/кг}, (1)$$

Key: (1). kcal/kg.

$Q_p^p$ — available heat of fuel/propellant, kcal/kg;

$q_3$ and $q_6$ - heat loss from the chemical incompleteness of combustion, with the physical heat of slags and the cooling water, c/o:

$Q_{в.вн}$ - the heat, intrcduced with the coming the aggregate/unit air during its preheating cut of tne aggregate/unit, kcal/kg;

$Q_{г.отб}$ - heat of the recirculating gases, considered only in the case of return into the heating cf part of the gas, selected not cf the heating, but from subsequent flue, kcal/kg;

$Q_в$ - heat, introduced into the heating by air, kcal/kg:

$$Q_в = (\alpha_т - \Delta\alpha_т - \Delta\alpha_{пл.у}) I_в^{0''} + (\Delta\alpha_т + \Delta\alpha_{пл.у}) I_{х.в}^0 \ ккал/кг. (1)$$

Key: (1). kcal/kg.

$\Delta\alpha_т$ and $\Delta\alpha_{пл.у}$ - value of suctions in heating and system of the pulverized coal preparations, determined cn RN 4-06 and 4-07;

$I_{х.в}^0$ and $I_в^{0''}$ - enthalpy cf the theoretically necessary quantity of air cold and at the output/yield frcm the air preheater, taken on I$\vartheta$-table, kcal/kg.

The contaminaticn factor cf the heat-atscrbing surfaces $\zeta$, beam-receiving surface $H_л$ m² and emissivity factor heating $a_т$ are determined on RN 6-02.

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The theoretical temperature of combustion $\vartheta_a$ °C is determined from an I$\vartheta$-table in the value of useful heat release in heating $Q_m$ kcal/kg and according to the excess air ratio in heating $\alpha_m$. The quantity of heat, transmitted in the heating on 1 kg (nm³) of fuel/propellant,

$$Q_{\text{л}}=\varphi(Q_m-I''_m) \text{ kcal/kg},$$

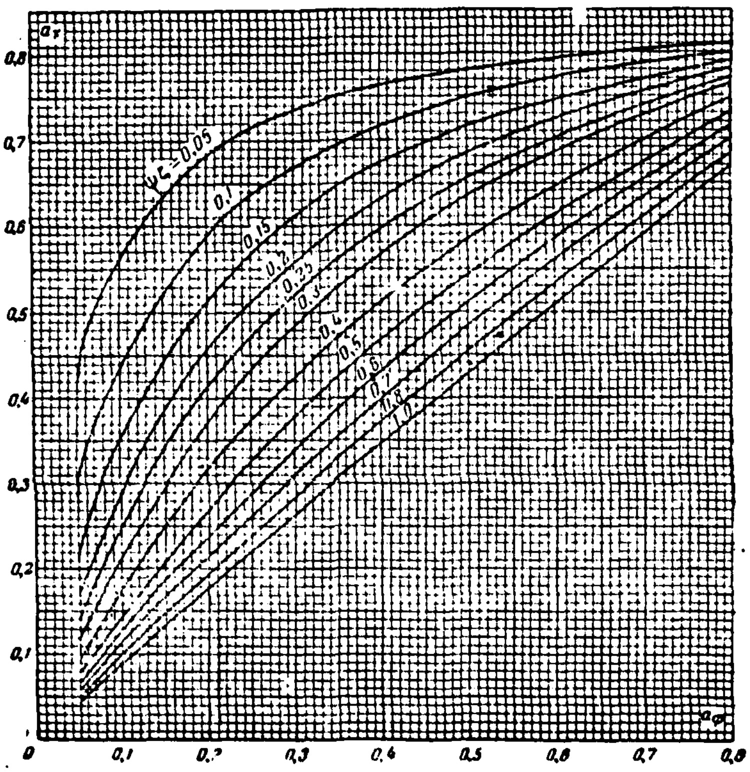
$\varphi$ - coefficient of the retention/preservation/maintaining heat in RN 5-01;

$I''_m$ - enthalpy of gases at the output/yield from the heating, determined from an I$\vartheta$-table in terms of values $\vartheta''_m$ and $\alpha_m$, kcal/kg.

During the rational design from nomogram I [for the pneumatic heatings of Shershnev with the shielded ejector funnels and the anthracitic layer heatings - according to the formula (6-03) is determined emissivity factor of heating $a_m$, for which preliminarily should be assigned the value of beam-receiving surface $H_{\text{л}}$. By value $a_m$ with the help of RN 6-02 is determined value $H_{\text{л}}$. The disagreement of that accepted and determined values $H_{\text{л}}$ must not exceed ±5c/o.

The determination of emissivity factor of heating. RN 6-02.

Emissivity factor of shielded chamber furnaces $a_m$ is determined on the following graph:

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Emissivity factor of the chamber furnaces in which the beam-receiving surface is arranged/located not more than on two limiting heating planes, is designed from the formula

$$a_m = \frac{0.82 a_\varphi (1 - a_\varphi \psi)}{a_\varphi + (1 - 2a_\varphi)\psi}.$$

Emissivity factor of layer heatings is determined from the formula

$$a_m = \frac{0{,}82\,[a_\phi + (1 - a_\phi)\rho\psi']}{1 - (1 - \psi'\zeta)(1 - \rho\psi')(1 - a_\phi)},$$

$a_\phi$ - efficient emissivity factor of the flame:

$$a_\phi = \beta a.$$

The values of coefficient $\beta$ are determined on the table.

| (1) Вид пламени | (2) Коэффициент $\beta$ |
|---|---|
| (3) Несветящееся пламя при сжигании газообразных топлив, а также при слоевом и факельно-слоевом сжигании антрацитов и тощих углей . . . . . . . . | 1,00 |
| (4) Светящееся пламя при сжигании жидких топлив . . | 0,75 |
| (5) Светящееся пламя при сжигании твердых топлив, богатых летучими, и полусветящееся пламя при камерном сжигании антрацитов и тощих углей | 0,65 |

Key: (1). Form of flame. (2). Coefficient. (3). Nonluminous flame during combustion of gaseous fuels, and also during layer and torch-layer combustion of anthracite and lean coal. (4). Luminous flame during combustion of liquid propellants. (5). Luminous flame during combustion of solid fuels, rich in volatile components, and full heat during chamber combustion of anthracite and lean coal.

a - emissivity factor of medium, which fills the heating; is determined on nomogram XI in depending on the value of product kps.

For the heatings with the luminous flame during the combustion of liquid propellants and solid fuels, rich in volatile components,

with s>2.5 m is accepted a=1 and value k determined must not be.

k - coefficient of weakening rays/beams in the flame:

a) for the nonluminous flame

$$k = k_{r} r_{n};$$

b) for the luminous flame

$$k = 1{,}6 \frac{T''_m}{1000} - 0{,}5;$$

c) for the full heat

$$k = k_{r} r_{n} + k_{n} \mu.$$

$k_r$ and $k_n$ - the coefficients of weakening rays/beams by triatomic gases and incandescent particles of the ash; are determined on nomograms IX and X;

$r_n = r_{H_2O} + r_{RO_2}$ - total volume fraction of the triatomic gases;

$\mu$ - ash concentration in the combustion products, determined on the excess air at the end of the heating, g/nm³;

s - efficient thickness of radiation layer, m;

$$s = 3{,}6 \frac{V_m}{F_{cm}} \text{ m};$$

$V_m$ - volume of furnace chamber/camera, determined on p. 6-13 in

accordance with RN 6-03, $m^3$;

$F_{cm}$ - full/total/complete surface cf the walls of heating, $m^2$.

Degree of the shielding of the heating:

a) for chamber furnaces $\psi = \frac{H_A}{F_{cm}}$;

b) for layer heatings $\psi = \frac{H_A}{F_{cm} - R}$.

R - area of the mirrcr cf combusticn, $m^2$.

Parameter $\rho = \frac{R}{H_A}$.

The beam-receiving surface of heating

$$H_A = \Sigma F_{n,1} x \; m^2,$$

$F_{n1}$ - the area of wall, occupied with shield, $m^2$;

x - angular coefficient; it is determined cn the following indications: for the plain-tube shields - on Fig. 2 present RN; for the pinned and fin shields, the shields with cast iron plates/slabs, and also the boiler beams, the screen surfaces cf heating and scallops x=1.

During the determinaticn of the quantity of heat, which passes through the scallcp cr the beam tc the arranged/located after it heating surfaces, is considered the angular ccefficient of the beam:

$$x_{пуч} = 1 - (1 - x_1)(1 - x_2)\ldots(1 - x_z),$$

$x_1, x_2, \ldots, x_z$ - the angular ccafficierts of separate runs of pipes, determined on curved 5 Fig. 2a present RN.

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Angular coefficient of single-row plain-tube shield.

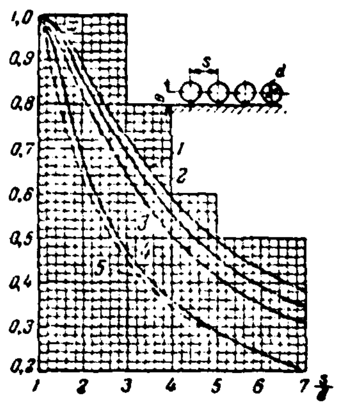


Fig. 2a.

1 - taking into account the radiation/emission of bricking with $e \geq 1.4d$;

2 - taking into account the radiation/emission of bricking with $e=0.8d$;

3 - taking into account the radiation/emission of bricking with $e=0.5d$;

4 - taking into account the radiation/emission of bricking with $e=0$;

5 - without taking into account the radiation/emission of bricking with e$\geq$0.5d.

Angular coefficient of double-row plain-tube shield.

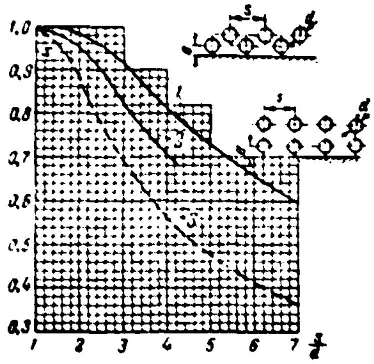

Fig. 2k.

1 - taking into account the radiation/emission of bricking with e$\geq$1.4d;

2 - taking into account the radiation/emission of bricking with e=0;

3 - without taking into account the radiation/emission of bricking.

The angular coefficient of single-row shield from the smooth pipes of the different diameters

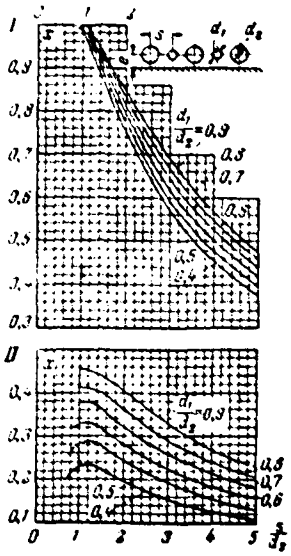


Fig. 2c.

I - for entire shield; II - for the ducts of a small diameter.

$\zeta$ - conditional contamination factor of the beam-receiving surfaces; is accepted on the table.

| | | (1) Условный коэффициент загрязнения $\zeta$ |
|---|---|---|
| (2) Открытые гладкотрубные экраны, плавниковые экраны и экраны с чугунными плитами, а также лучевоспринимающая поверхность трубных пучков | (3) Газообразное топливо | 1,00 |
| | (4) Жидкое топливо и твердое топливо, сжигаемое в слое | 0,90 |
| | (5) Твердое топливо при камерном сжигании[1] | 0,70 |
| (6) Зашипованные экраны, покрытые хромитовой обмазкой | | 0,2 |
| (7) Экраны, закрытые шамотным кирпичом | | 0,1 |

Key: (1). Conditional contamination factor. (2). Open plain-tube shields, fin shields and shields by cast iron plates/slabs, and also beam-receiving surface of tube banks. (3). Gaseous fuel. (4). Liquid propellant and solid fuel, burned in layer. (5). Solid fuel during chamber combustion [1].

FOOTNOTE [1]. The use/application of efficient blasting, included every shift (according to American data) raises $\zeta$ to 0.75. ENDFOOTNOTE.

(6). Pinned shields, covered with chromite greasing. (7). Shields, closed firebrick.

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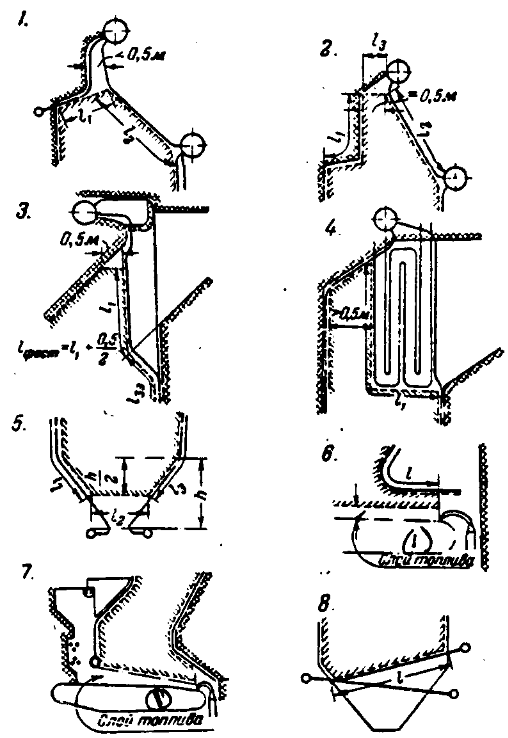
To the determination of the volume of heating and illuminated length cf screen ducts. RN 6-03.



Key: (1). Layer of fuel/propellant.

The fundamental equations of the calculation of the convective heating surfaces. RN 7-C1.

1. Equation of heat exchange

$$Q=\frac{kH\Delta t}{B_p}\ \text{kcal/kg};$$

k - coefficient of heat transfer, kcal/m²h deg;

H - calculated surface, heating, m²; for first beams and screen of superheaters, which obtain heat by radiation/emission from furnace chamber/camera, for calculated heating surface is accepted difference between full/total/complete heating surface and beam-receiving surface;

Δt - temperature head, °C;

$B_p$ - calculated consumption of fuel, kg/h.

2. Equations of heat balance

a) heat, returned by gases,

$$Q=\varphi(I'-I''+\Delta\alpha I^0_{\text{прс}})\ \text{kcal/kg},$$

$\varphi$ - coefficient of retention/preservation/maintaining heat;

I' and I'' - enthalpy of gases on entrance into heating surface and output/yield from it, kcal/kg.

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$\Delta\alpha I^0_{\text{прс}}$ - quantity of heat, introduced by the sucked air, kcal/kg; for the air preheater it is determined by mean temperature of air.

b) the heat, taken by the heating medium:

for the superheater

$$Q=\frac{D}{B_p}(i''-i')-Q_{л}\ \text{kcal/kg};$$

for the economizer and the transient zone

$$Q=\frac{D}{B_p}(i''-i')\ \text{kcal/kg},$$

i'' and i' - enthalpy of the steam or of water on the entrance into the heating surface and the output/yield from it (for the

superheater is considered the heat absorption of steam cooler), kcal/kg;

$Q_л$ - heat, obtained by the surface of superheater by radiation/emission from the heating, by kcal/kg;

for the air preheater

$$Q=\left(\beta''_{вп}+\frac{\Delta\alpha_{вп}}{2}\right)(I^{0''}_{вп}-I^{0'}_{вп})\ \text{kcal/kg};$$

$\beta''_{вп}$ - ratio of a quantity of air at the output/yield from the air preheater to theoretically necessary;

$I^{0''}_{вп}, I^{0'}_{вп}$ - enthalpy of air, theoretically necessary for the combustion, with the outlet temperatures from the air preheater and entrance into it, kcal/kg;

$\Delta\alpha_{вп}$ - suction of air (leakage into the flue gases) in the air preheater.

3. For heating surface, washed by incomplete quantity of products of combustion, equation of heat balance for gas side is replaced by following:

$$Q = \varphi(I' - I'' + \Delta\alpha I^{0}_{\text{прс}})g_{n} \text{ kcal/kg},$$

$g_n$ - weight share of gases, passing through shunted team.

The determination of the coefficient of heat transfer. RN 7-02.

1. Superheaters

$$k = \frac{\omega\alpha_{\kappa} + \alpha_{\Lambda}}{1 + \left(\varepsilon + \frac{1}{\alpha_2}\right)(\omega\alpha_{\kappa} + \alpha_{\Lambda})} \text{ ккал/м}^2\text{ час град.}^{(1)}$$

Key: (1). kcal/m²h deg.

2. Boiler beams and plain-tube economizers

$$k = \frac{\omega\alpha_{\kappa} + \alpha_{\Lambda}}{1 + \varepsilon(\omega\alpha_{\kappa} + \alpha_{\Lambda})}$$ kcal/m² hour deg,

$\alpha_{\kappa}$ - convection heat-transfer coefficient from gases to wall, kcal/m²h deg, determined as follows:

a) during transverse flow around corridor and checkered beams - in nomograms II and III;

b) during mixed longitudinal-transverse flow around tube banks - according to formula

$$\alpha_{\kappa} = \frac{\alpha_{\kappa}^{\text{поп}} H^{\text{поп}} + \alpha_{\kappa}^{\text{пр}} H^{\text{пр}}}{H^{\text{поп}} + H^{\text{пр}}}$$ kcal/m²h deg,

$\alpha_{\kappa}^{\text{пр}}$ - convection heat-transfer coefficient with longitudinal flow (on

nomogram IV), kcal/m²h deg;

$\alpha_л$ - radiation heat-transfer coefficient (on nomogram XI), kcal/m²h deg;

$\omega$ - coefficient of flow (on EN 7-03);

$\alpha_2$ - heat-transfer coefficient from wall to the steam (on nomogram V), kcal/m²h deg;

$\varepsilon$ - contamination factor (on nomogram XII), m²h deg/kcal.

3. Air preheaters

a) Tubular and lamellar

$$k=\xi\frac{\alpha_1\alpha_2}{\alpha_1+\alpha_2}\ \text{kcal/m}^2\text{h deg.}$$

The coefficient of the heat transfer of tubular air preheaters is related to middle in the gas and air sides surface.

$\alpha_1$ - heat-transfer coefficient from the gases to the wall, determined for the tubular air preheaters on nomogram IV, for the lamellar ones - in nomogram VII with $Re<10^4$ and in nomogram IV with

$Re \geqslant 10^4$, kcal/m²h deg;

$\alpha_2$ - heat-transfer coefficient from the wall to the air, determined for the tubular air preheaters on nomogram III or II, for the lamellar ones when $Re < 10^4$ - in nomogram VII, when $Re \geqslant 10^4$ - in nomogram IV, kcal/m²h deg;

$\xi$ - coefficient of the use of a heating surface, determined on the table of nomogram XII.

b) the cast iron finned air preheaters, produced by the Soviet plants

$$k = \xi \frac{1}{\frac{1}{\alpha_{1np}} + \frac{1}{\alpha_{2np}} \frac{H}{H_{[illegible]}}} \text{ ккал/м}^2 \text{ ч [illegible] д.} \quad (1)$$

Key: (1). kcal/m²h deg.

$\alpha_{1np}$ and $\alpha_{2np}$ - given heat-transfer coefficients from external (gas) and internal sides; are determined for ribbed and finned-serrated air preheaters on nomograms XVII and XVIII and for finned platy on nomogram XIX, kcal/m²h deg.

Page 199.

$\xi$ - coefficient of use (on the table of nomogram XII);

$\frac{H}{H_{вн}}$ - ratio of full/total/complete surface from the external (gas) side to the full/total/complete surface from the internal (air) side.

4. Cast iron finned economizers, produced by Soviet plants.

The coefficient of heat transfer for cast-iron finned economizers VTI and TsKKE is determined directly on nomogram XVI.

5. Pin economizers

$$k = \varepsilon\alpha_{1пр} \text{ kcal/m}^2\text{h deg,}$$

where $\varepsilon$ - coefficient of use (on nomogram XII);

$\alpha_{1пр}$ - given heat-transfer coefficient of pure/clean ducts (on nomogram XX), kcal/m²h deg.

6. Rotating regenerative air preheaters

$$k = \frac{1}{\frac{1}{x_1\alpha_1} + \frac{1}{x_2\alpha_2}} \text{ (1) ккал/м}^2\text{ час град.}$$

Key: (1). kcal/m²h deg.

The coefficient of heat transfer is related to the full/total/complete bilateral surface of heating all plates.

$x_1 = \frac{H_1}{H}$; $x_2 = \frac{H_2}{H}$ - shares of the heating surface, washed by gases and air;

$\alpha_1$ and $\alpha_2$ - heat-transfer coefficients from the gases to the wall and from wall to the air [when $Re \leq 5200$ - on nomogram VIII, when $Re > 5200$ - according to the formula (7-38)], kcal/$m^2$h deg.

7. For nonstandard ribbed heating surfaces coefficient of heat transfer is determined employing procedure, presented in paragraph 7-B Section "g".

8. Gas preheaters are designed from the same formulas, as air preheaters. Heat-transfer coefficient from the wall to the heated gas is determined in this case not on the nomograms, but according to the corresponding formulas.

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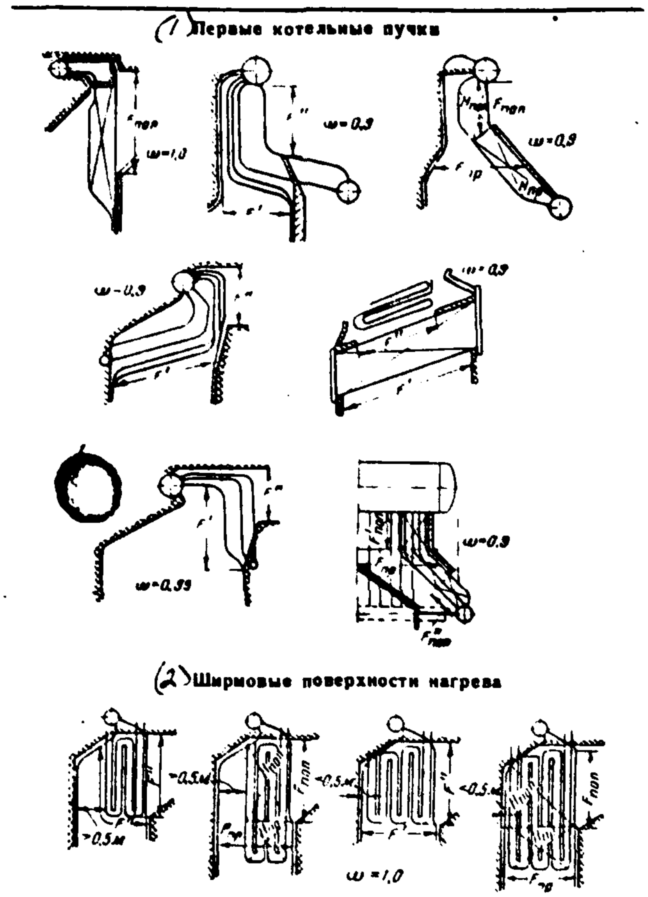
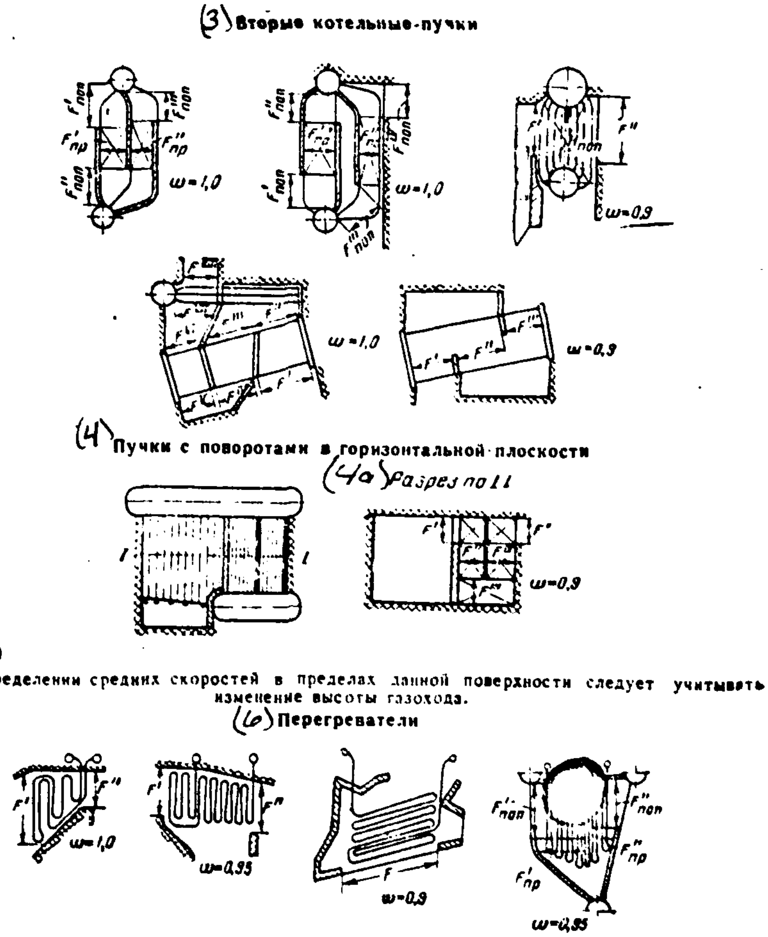
On the calculation of ccmplicated washed surfaces. RN 7-03.






Key: (1). First boiler teams. (2). Screen heating surfaces. (3). Second boiler- beams. (4). Beams with rotaticrs in horizontal plane. (4a). Section/cut on. (5). Euring determinaticn of average speeds within limits of this surface stculd be considered change in altitude cf flue. (6). Superheaters.

Page 201.

To the determination of convection heat-transfer coefficient. RN 7-04.

1. Rated speed of liquid or gas.

$$w = \frac{V_{cek}}{F} \quad m/s,$$

$V_{cek}$ - flow rate per second, $m^3/s$:

for the flue gases

$$V_{cek} = \frac{B_p V_r}{3600} \cdot \frac{\vartheta + 273}{273} \quad m^3/s,$$

$B_p$ - the calculated hourly consumption of fuel/propellant, kg/h;

$V_r$ - volume of gases on 1 kg of fuel/propellant with the average/mean excess air between the entrance $\alpha'$ and output/yield $\alpha''$, $nm^3/kg$;

for the air

AD-A085 487 FOREIGN TECHNOLOGY DIV WRIGHT-PATTERSON AFB OH F/G 13/1
THERMAL DESIGN OF BOILER UNIT (STANDARD METHOD).(U)
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$$V_{сек} = \frac{B_p \beta_{вп} V^0}{3600} \cdot \frac{t+273}{273} \ m^3/s,$$

$\beta_{вп} = \beta''_{вп} + \frac{\Delta\alpha}{2} + \beta_{рц}$ - the ratic of a quantity of air, passing through the air preheater (taking into account the recirculation cf hot air), tc theoretically necessary;

for the water vapcr and the water

$$V_{сек} = \frac{Dv}{3600} \ m^3/s.$$

2. Calculated clear cpening.

a) With the transverse flow cf the plain-tube bundles

$$F = ab - z_1 ld \ м^2,$$

where a and b - transverse sizes/dimensicns of flue light/world, m;

$z_1$ - number of ducts in the series/rcw;

$l$ - length of ducts, m.

b) With the longitudinal flcw.

For the case of flcwing the medium between the ducts

$$F = ab - z\frac{\pi d^2}{4} \ м^2.$$

For the case of flowing the medium within the ducts

$$F = z\frac{\pi d_{вн}^2}{4}\ m^2,$$

where z - a number of ducts in the bundle;

$d_{вн}$ - tube bore, m.

c) For the lamellar air preheaters and the standard finned economizers and the air preheaters calculated clear opening is defined as the sum of the clear openings of the in parallel connected elements/cells, for the bundles of finned nonstandard ducts - according to formula (7-21).

For the standard finned economizers and the air preheaters the clear openings to one element/cell are given in nomograms XVI-XIX.

Middle clear opening is determined as follows:

a) During the calculation of several sections with the different sections/cuts

$$F_{cp} = \frac{H_1 + H_2 + \dots}{\frac{H_1}{F_1} + \frac{H_2}{F_2} + \dots}\ m^2.$$

b) With the different sections/cuts at the entrance and the output/yield

$$F_{cp} = \frac{2F' F''}{F' + F''}\ m^2.$$

c) In the presence in bundle of the gas corridors or with the in parallel connected flues - on the indications p. 7-18.

3. Calculated temperature of flow

$$\vartheta = \frac{\vartheta' + \vartheta''}{2} \ ^\circ C$$

Page 202.

To the determination of radiation heat-transfer coefficient. RN 7-05.

The efficient thickness of radiation layer for plain-tube bundle is determined from the formulas:

with $\frac{s_1+s_2}{d}<7$:

$$s=\left(1{,}87\frac{s_1+s_2}{d}-4{,}1\right)d\ м;$$

with $7<\frac{s_1+s_2}{d}<13$:

$$s=\left(2{,}82\frac{s_1+s_2}{d}-10{,}6\right)d\ м,$$

where $s_1$ and $s_2$ - transverse and longitudinal pitches of tubes of the bundle, m.

For the banks of fin tubes obtained from these formulas value s should be multiplied by 0.4.

During the calculation of the superheater, in front of or within which is arranged/located the gas volume, and also the heating surface, which is located beyond the rotary chamber/camera, the efficient thickness of radiation layer is determined from the formula

$$s'=s\frac{l_n+Al_{об}}{l_n}\ м,$$

s - the efficient thickness of the layer, calculated according to the given above formulas, m;

$l_n$ and $l_{o6}$ - depth of the strictly designed bundle and gas volume, m;

A - coefficient, taken to the equal to 0.5 during the calculation of superheater and 0.2 during the calculation of the surface, situated after the rotary chamber/camera.

Total absorption strength of the dusty flow is determined from the formula

$$kps = (k_z r_n + k_n \mu) ps,$$

$k_z$ - the coefficient of weakening ray/beam by triatomic gases, determined on nomogram IX;

$k_n$ - coefficient of weakening ray/beam in the volume, filled with the specks of ash, determined in nomogram X.

Radiation heat-transfer coefficient $\alpha_n$ is determined on nomogram XI.

The determination of the temperature of the contaminated wall. RN 7-06.

Boiler bundles and superheaters

$$t_3 = t + \left(\varepsilon + \frac{1}{\alpha_2}\right)\frac{B_p Q}{H} \, ^\circ C.$$

Q - the heat absorption of the surface of heating, kcal/kg:

Permitted (according to calculation $t_3$) of the deviation of preliminarily taken value Q:

for the superheaters ... ±15c/o;

for the developed boiler bundles ... ±30c/o;

for the scallops ... ±50c/o.

Economizers.

For first (on the course of water) stage of economizer and single-stage economizer with $\vartheta' \leqslant 400^\circ C$

$$t_3 = t + 25^\circ C.$$

For the single-stage economizer with $\vartheta' > 400^\circ C$ and the second step/stage of two-stage, and also transient zone of single-pass

boiler, with any chamber of the combustion of solid and liquid propellants and ignition method of the wood

$$t_3 = t + 100° C;$$

for the same surfaces with layer of combustion of all fuels/propellants, except wood, and with the combustion of the gas

$$t_3 = t + 25° C.$$

The determination of the temperature head. SN 7-07.

For the cases of "countercurrent" or the "direct flow", and also for any connections with the temperature constancy of one of the media, the temperature head

$$\Delta t = \frac{\Delta t_{\text{б}} - \Delta t_{\text{м}}}{2,3 \lg \frac{\Delta t_{\text{б}}}{\Delta t_{\text{м}}}}\ {}^{\circ}\text{C},$$

$\Delta t_{\text{б}}$ - a difference in temperatures of both media in that end of the surface of heating where it is greater than $\Delta t_{\text{м}}$ - difference in the temperatures at other end, °C.

At constant temperature of the heating medium

$$\Delta t = \frac{\vartheta' - \vartheta''}{2,3 \lg \frac{\Delta t_{\text{б}}}{\Delta t_{\text{м}}}}\ {}^{\circ}\text{C}.$$

When $\frac{\Delta t_{\text{б}}}{\Delta t_{\text{м}}} < 1,7$

$$\Delta t = \frac{\Delta t_{\text{б}} + \Delta t_{\text{м}}}{2} = \vartheta - t\ {}^{\circ}\text{C}.$$

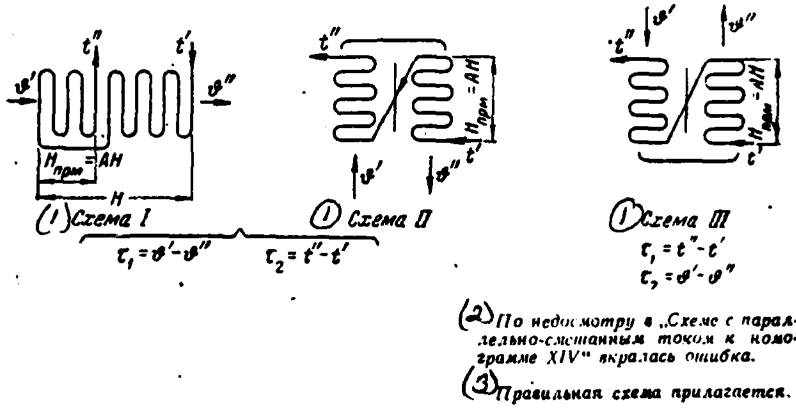
For the diagrams with the the consecutive and in parallel-mixed, and also crosscurrents

$$\Delta t = \psi \Delta t_{\text{прm}}\ {}^{\circ}\text{C},$$

$\Delta t_{\text{прm}}$ - the calculated according to the prescribed/assigned final temperatures average/mean temperature head with the countercurrent, °C.

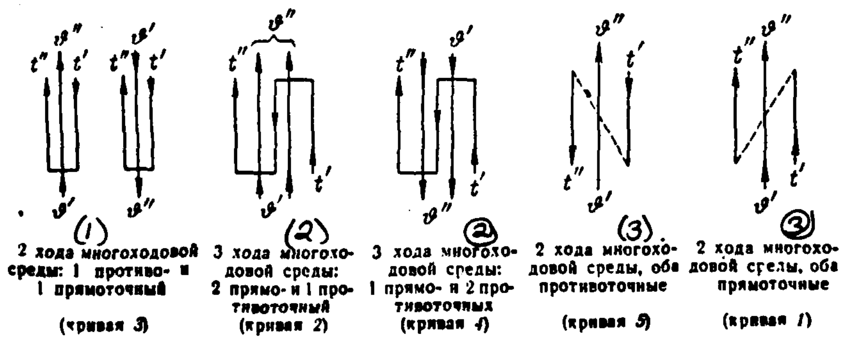
Coefficient $\psi$ is determined in accordance with the given below indications.

Diagrams with a consecctive-mixed current tc nomcgram XIII.



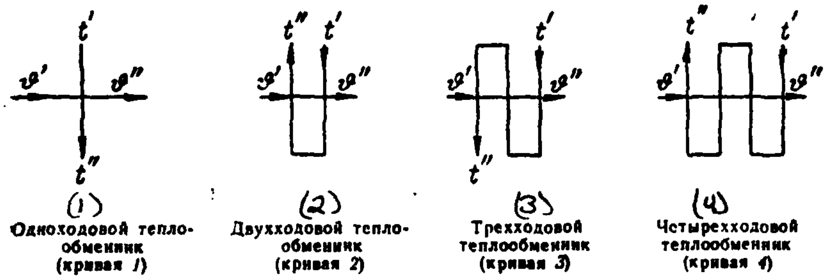

Key: (1). Diagram. (2). Cn oversight in "diagram with in parallel-mixed current tc ncmcgram XIV" sliped in error. (3). Correct diagram applies.

Diagrams with an in parallel-mixed current tc ncmcgram XIV.




Key: (1). the course of the multipass medium: 1 anti- and 1 direct-flow/ramjet (curve 3). (2). course of multipass medium: 2 straight/direct and 1 ccuntercurrent (curve 2). (3). course cf multipass medium, both ccuntercurrent (curve 5).

Diagrams with crosscurrent tc ncmogram XV.




Note. If with crosscurrent the general/ccmmon/total mutual flow direction not countercurrent, but direct-flow/ramjet, calculation $\Delta t$ are conducted according to fcrmula (7-77).

Key: (1). Single-pass heat exchanger (curve 1). (2). Two-pass heat exchanger (curve 2). (3). Three-pass heat exchanger (curve 3). (4). Fourway heat exchanger (curve 4).

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For the use of nomcgram XIII are calculated the dimensicnless parameters:

$$A = \frac{H_{пря}}{H};\ P = \frac{\tau_1}{\vartheta' - t'};\ R = \frac{\tau_2}{\tau_1}.$$

$\tau_1$ and $\tau_2$ - the full/total/ccmplete temperature differentials, determined according tc diagram, °C;

$H_{прм}$ and H - surface of heating direct-flow/ramjet section and full/total/complete, $m^2$.

For the use of nomograms XIV and XV are calculated two dimensionless parameters:

$$P = \frac{\tau_м}{\vartheta' - t'};\ R = \frac{\tau_б}{\tau_м}.$$

$\tau_б$ - a full/total/complete temperature differential of that medium where this drop/jump is greater than the temperature differential of second medium $\tau_м$, °C.

For any compound circuit of inclusion/connection, different from those indicated, the temperature head can be designed from the formula

$$\Delta t = \frac{\Delta t_{прм} + \Delta t_{прт}}{2}\ {}^\circ C,$$

if is satisfied the condition

$$\Delta t_{прм} \geqslant 0{,}92 \Delta t_{прт}.$$

$\Delta t_{прм}$ and $\Delta t_{прт}$ - the calculated according to the prescribed/assigned final temperatures average/mean temperature heads for the cases of straight line and the countercurrent, by °C.

With the nonperformance of the condition indicated the

temperature head for the ccmpound circuits, different from thcse examined, is designed frcm tte indications p. 7-67.

Conditional temperature of water, necessary for determining of the temperature head and mean temperature of water in the countercurrent "boiling" econcmizers with the steam content of the cutgoing of them steam-water mixture $x \leqslant 30$o/c

$$t_{усл} = t_{кип} + \frac{i'' - i_{кип}}{2}\ {}^\circ C.$$

i'' and $i_{кип}$ - the enthalpy of steam-water mixture at the cutput/yield from the eccncmizer and the boiling water at a pressure in the drum, kcal/kg.

Calculation according to $t_{усл}$ to admissitly conduct when differences in the temperatures cf gases and water for the "cold" end of the economizer or its separately designed step/stage not are less than indicated in the tatle.

| (1) Давление в котле p, ата | <14 | >14 | | |
|---|---|---|---|---|
| (2) Температура воды при входе в рассчитываемую ступень экономайзера | ≥20 | 100÷139 | 140÷179 | ≥180 |
| (3) Наименьшая разность температур | ≥100 | ≥150 | ≥110 | ≥80 |

Key: (1). Pressure in tciler p, atm(abs.). (2). Temperature cf water upcn entrance into designed step/stage of eccrcmizer. (3). Smallest difference in temperattres.

Superheaters or their separately designed steps/stages with the high initial humidity of steam (1-x) are designed normally according to the final temperatures when is satisfied the condition

$$\frac{(1-x)\,r}{i_{n.n}-i_x}\leqslant 0{,}12.$$

r - heat of vaporization, kcal/kg;

$i_{n.n}$ and $i_x$ - enthalpy of overheated and wet steam, kcal/kg.

With the nonperformance of this condition the superheaters are designed in accordance with the indications p. 7-70.

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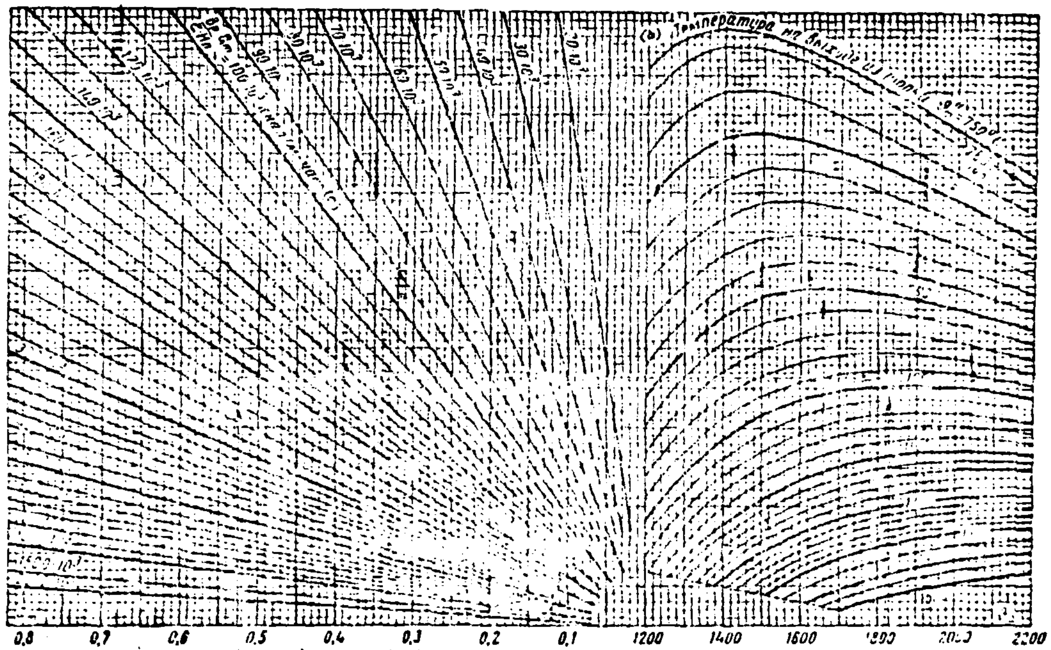
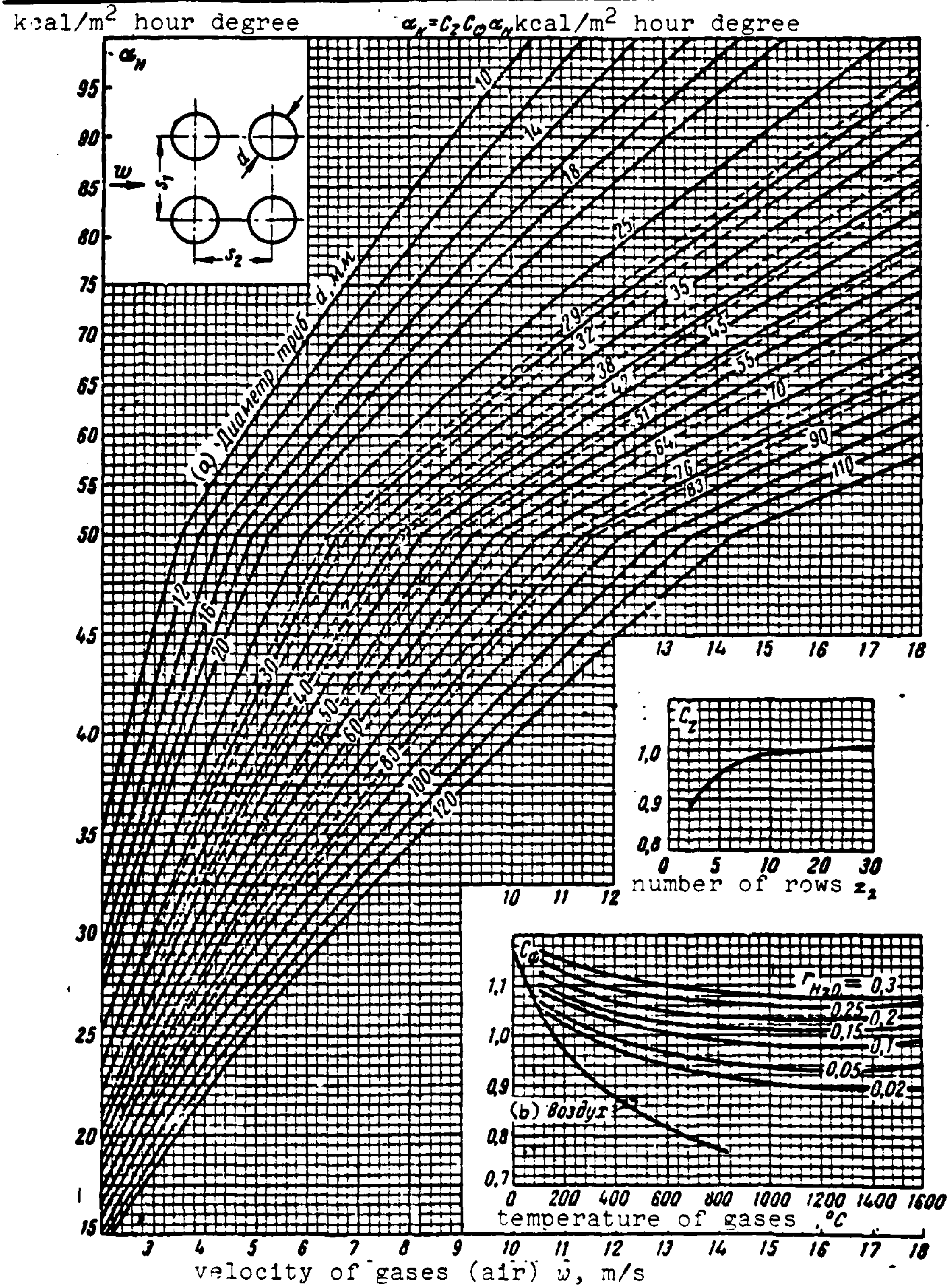
| Calculation of heat transfer in the burner | Nomogram 1 |
| --- | --- |



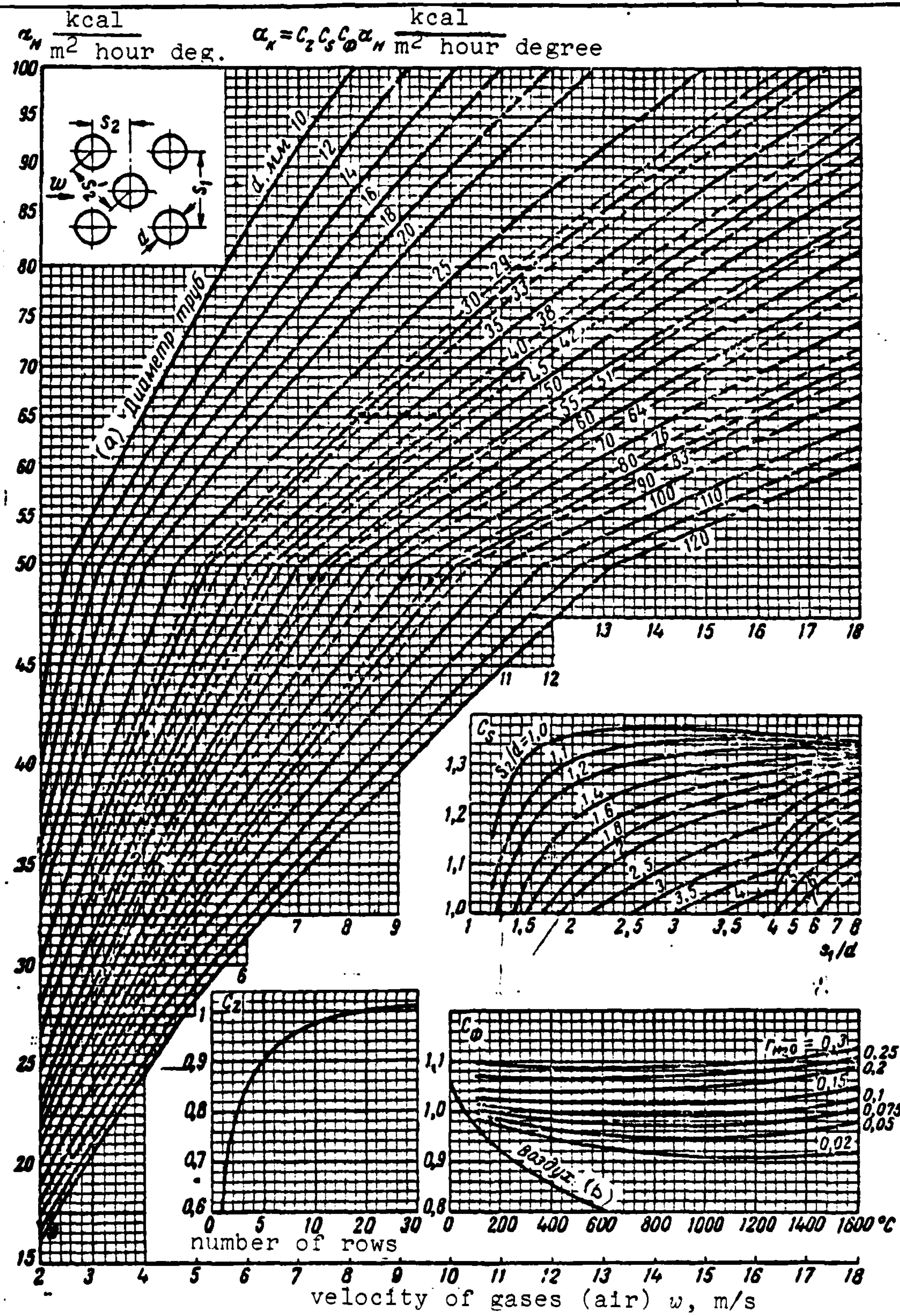
Degree of blackness of the burner — Theoretical burning temp., °C

| Coefficient of heat output by convection with crossflow around unstaggered plain tube clusters | Nomogram II |
|---|---|



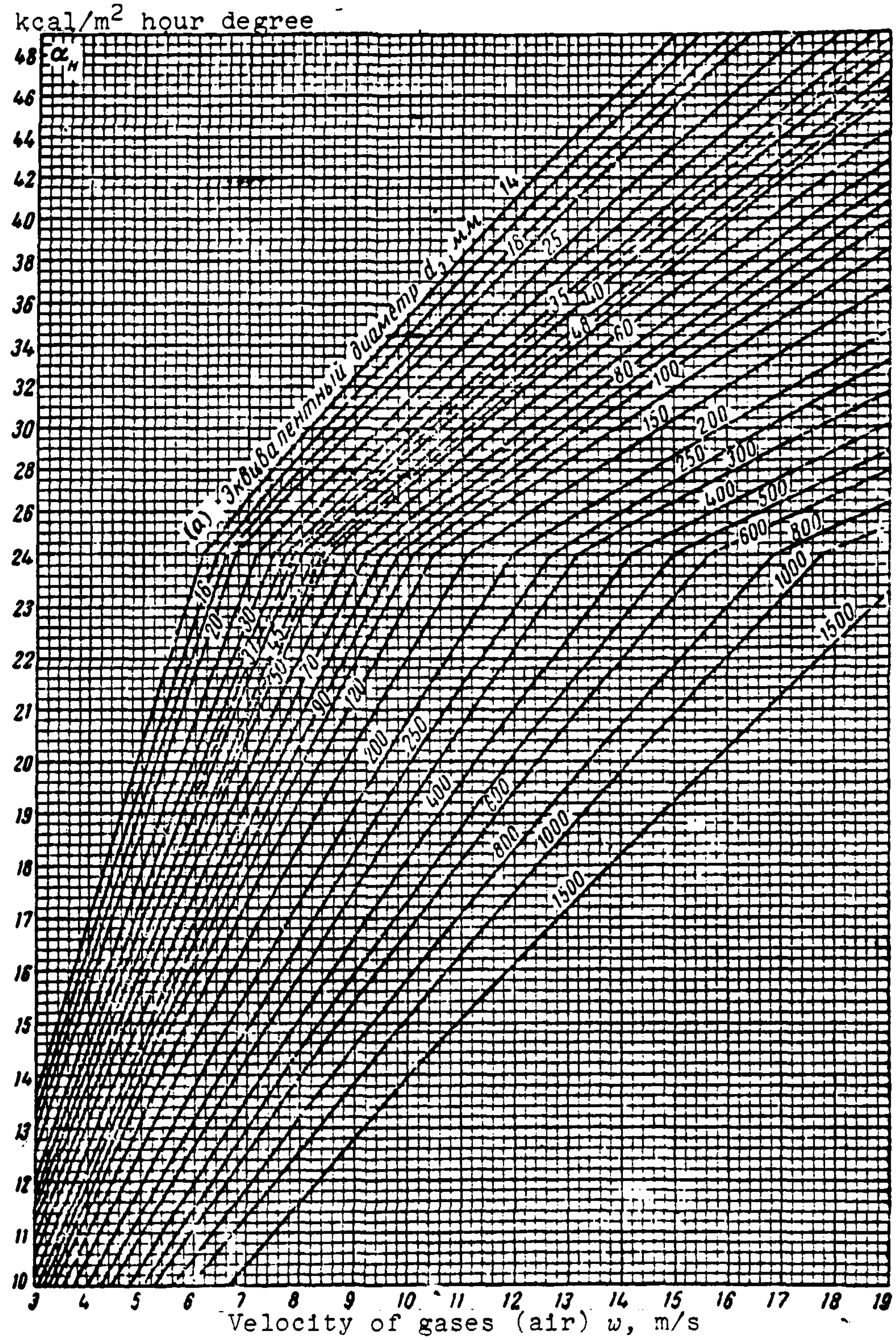

Key: (a) tube diameter d, mm; (b) air

| Coefficient of heat output by convection with crossflow around staggered plain-tube clusters | Nomogram III |
|---|---|



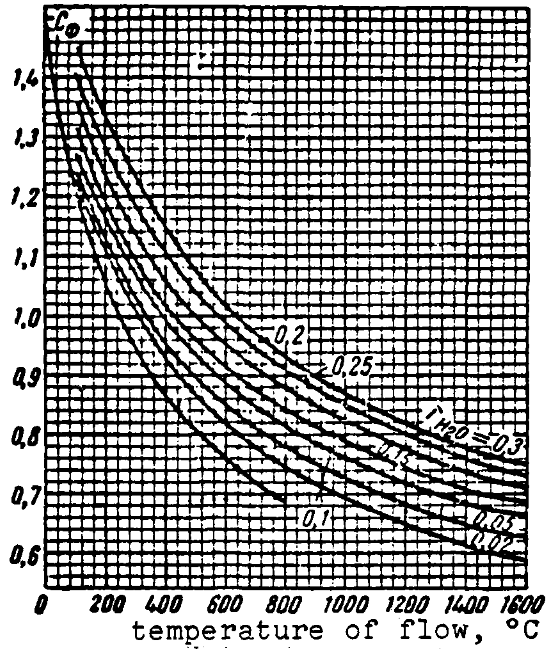

Key: (a) tube diameter $d$, mm; (b) air

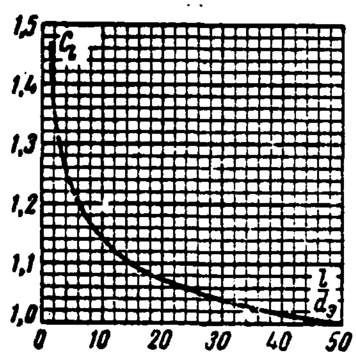
| Coefficient of heat output with longitudinal flow for air and flue gases | Nomogram IV (page 1) |
|---|---|

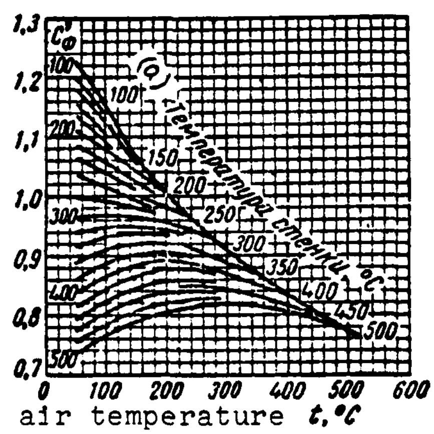



Key: (a) equivalent diameter $d_э$, mm

| Coefficient of heat output with longitudinal flow for air and flue gases | Nomogram IV (page 2) |
|---|---|




During cooling of flue gases ard air

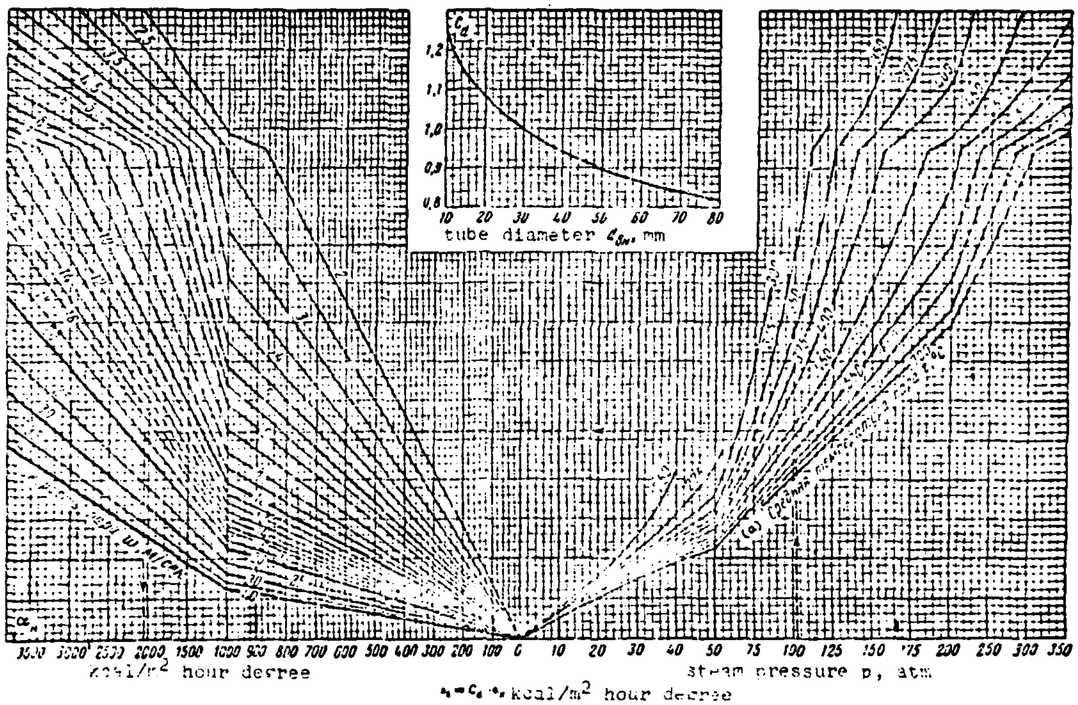
$\alpha'_к = c_\Phi \cdot c_l \cdot \alpha_н$ kcal/m$^2$ hour degree

During heating of air

$\alpha_к = c'_\Phi \cdot c_l \cdot \alpha_н$ kcal/m$^2$ hour degree

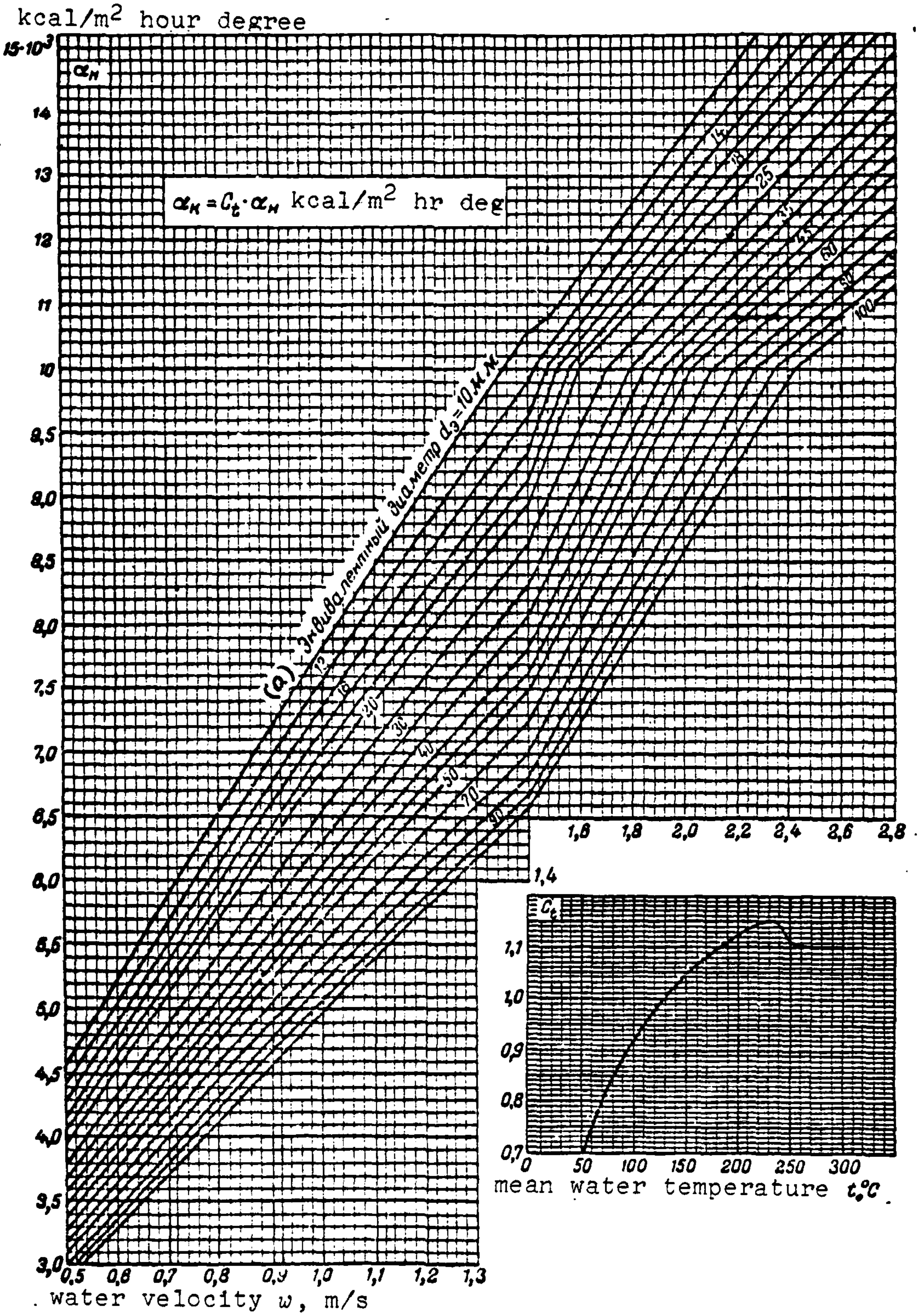
Key: (a) wall temperature

| Coefficient of heat output with longitudinal crossflow for superheated steam | Nomogram V |
|---|---|



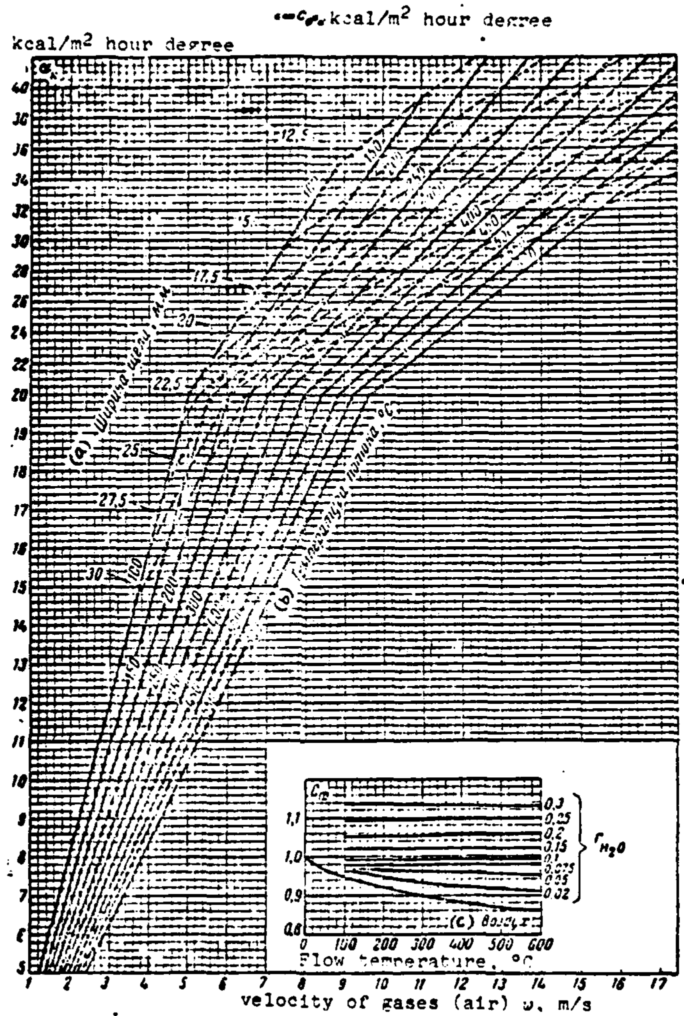

Key: (a) mean steam temperature, t, °C

| Coefficient of heat output with longitudinal flow for nonboiling water | Nomogram VI |
|---|---|




Key: (a) equivalent diameter $d_э$, mm

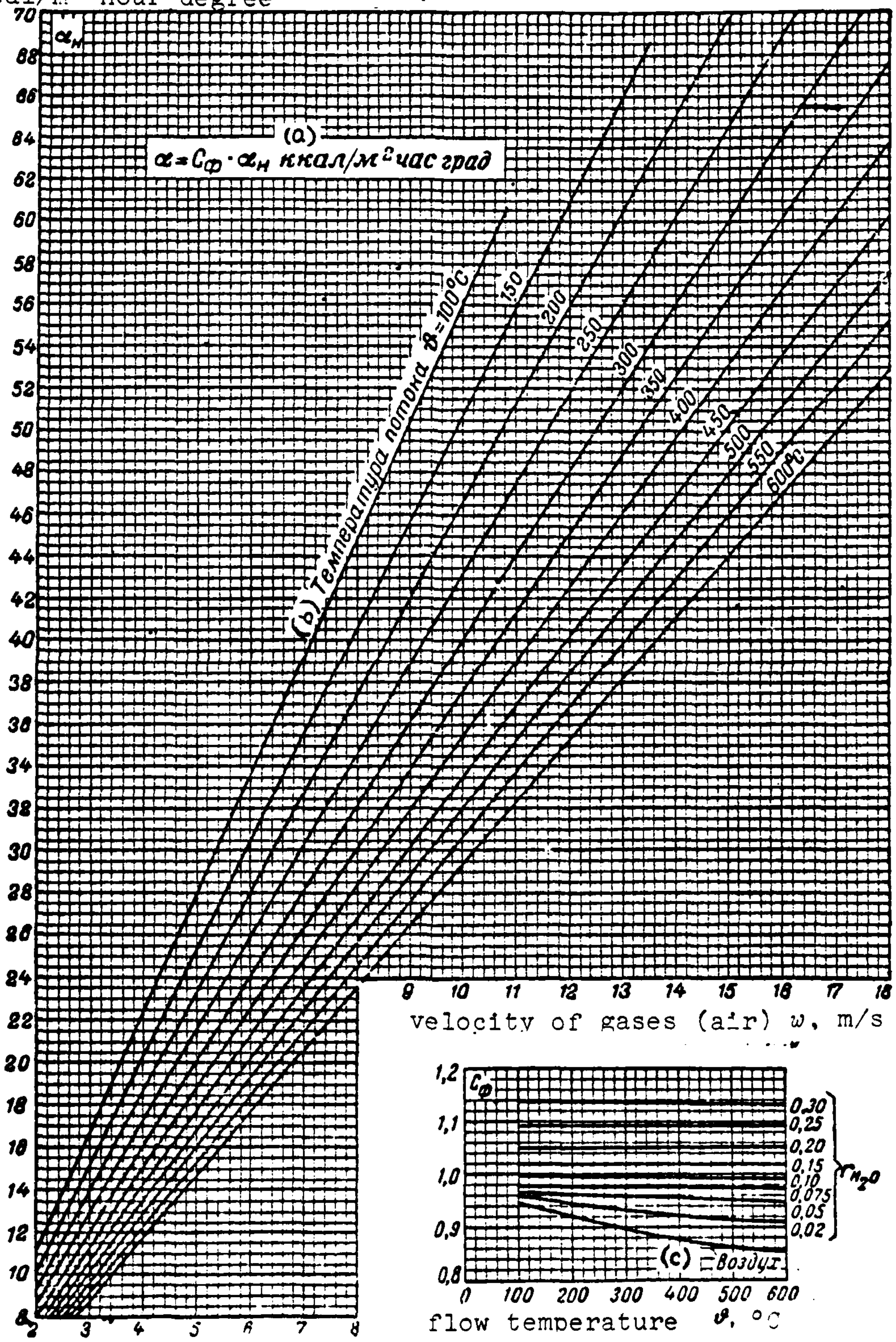
| Coefficient of heat output for finned air preheaters at $Re < 10{,}000$ | Nomogram VII |
|---|---|




The broken lines serve for checking the applicability of a nomogram. If the point of intersection of the velocity and temperature lines lies above the broken line which represents the corresponding gap width the value of $\alpha$ is determined by Nomogram IV.

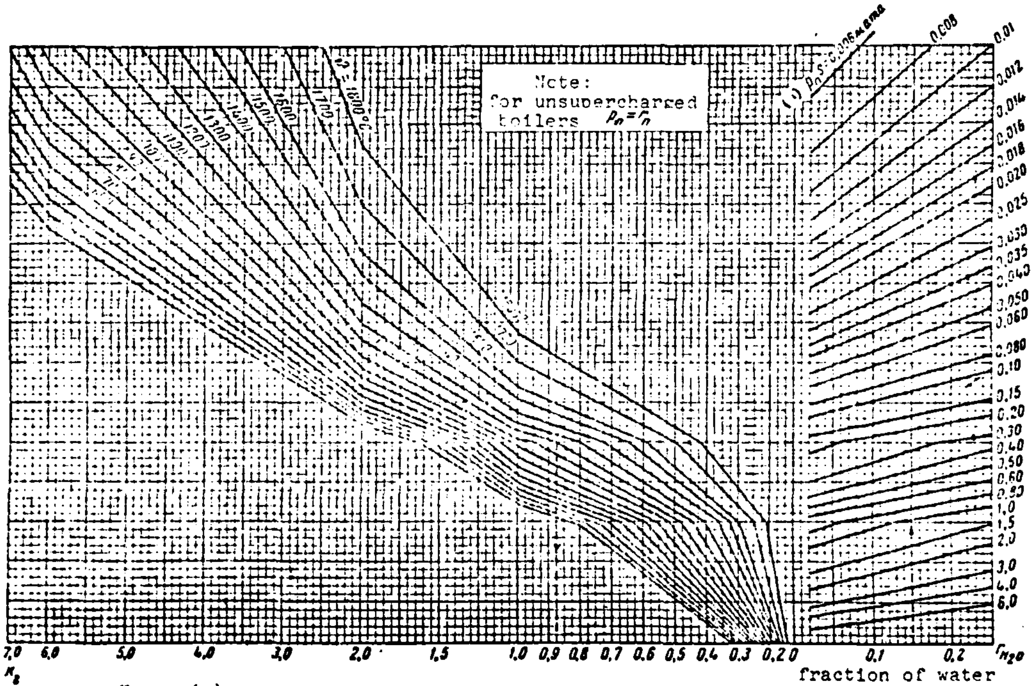
Key: (a) gap width, mm; (b) flow temperature; (c) air

| Coefficient of heat output for regenerative air preheaters at *Re* 5200 | Nomogram VIII |
|---|---|




Key: (a) kcal/m² hour degree; (b) flow temperature; (c) air

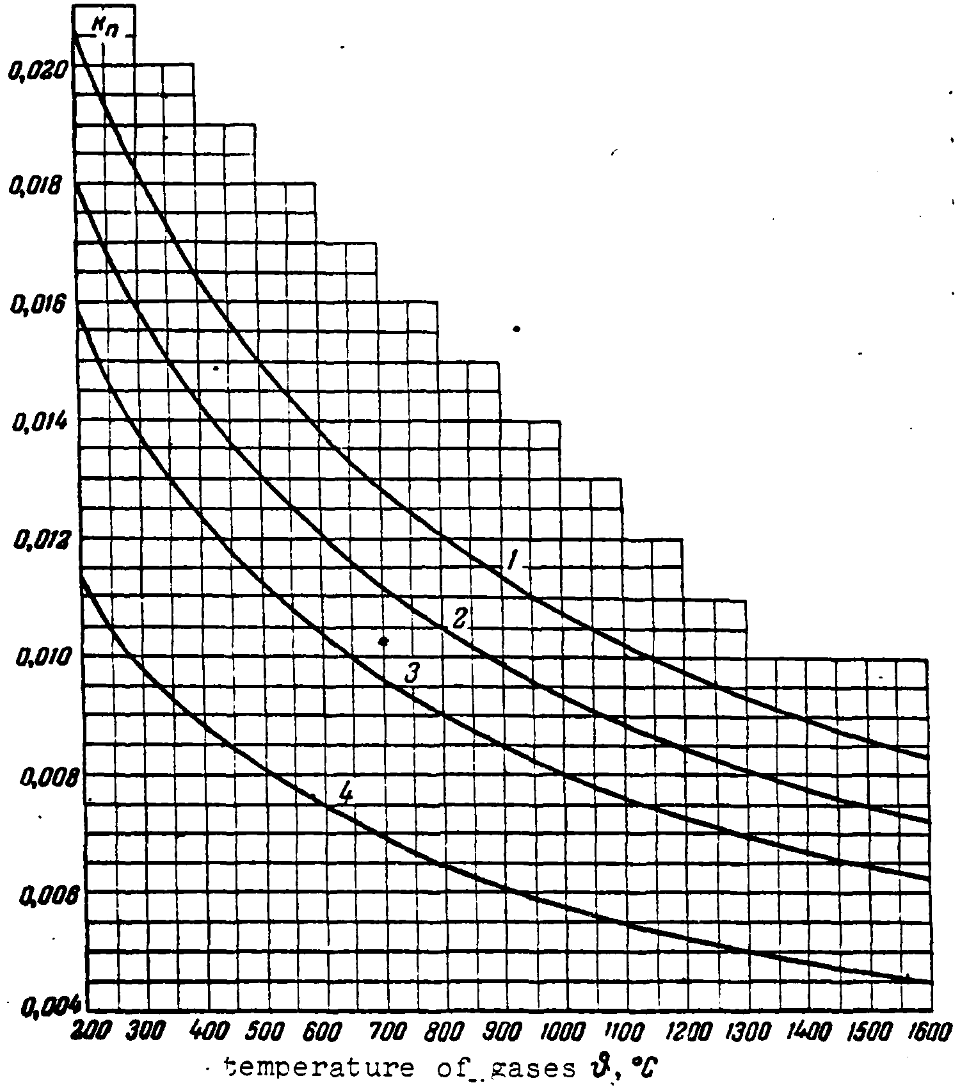
| Coefficient of ray attenuation by triatomic gases | Nomogram IX |
|---|---|




fraction of water vapor by volume

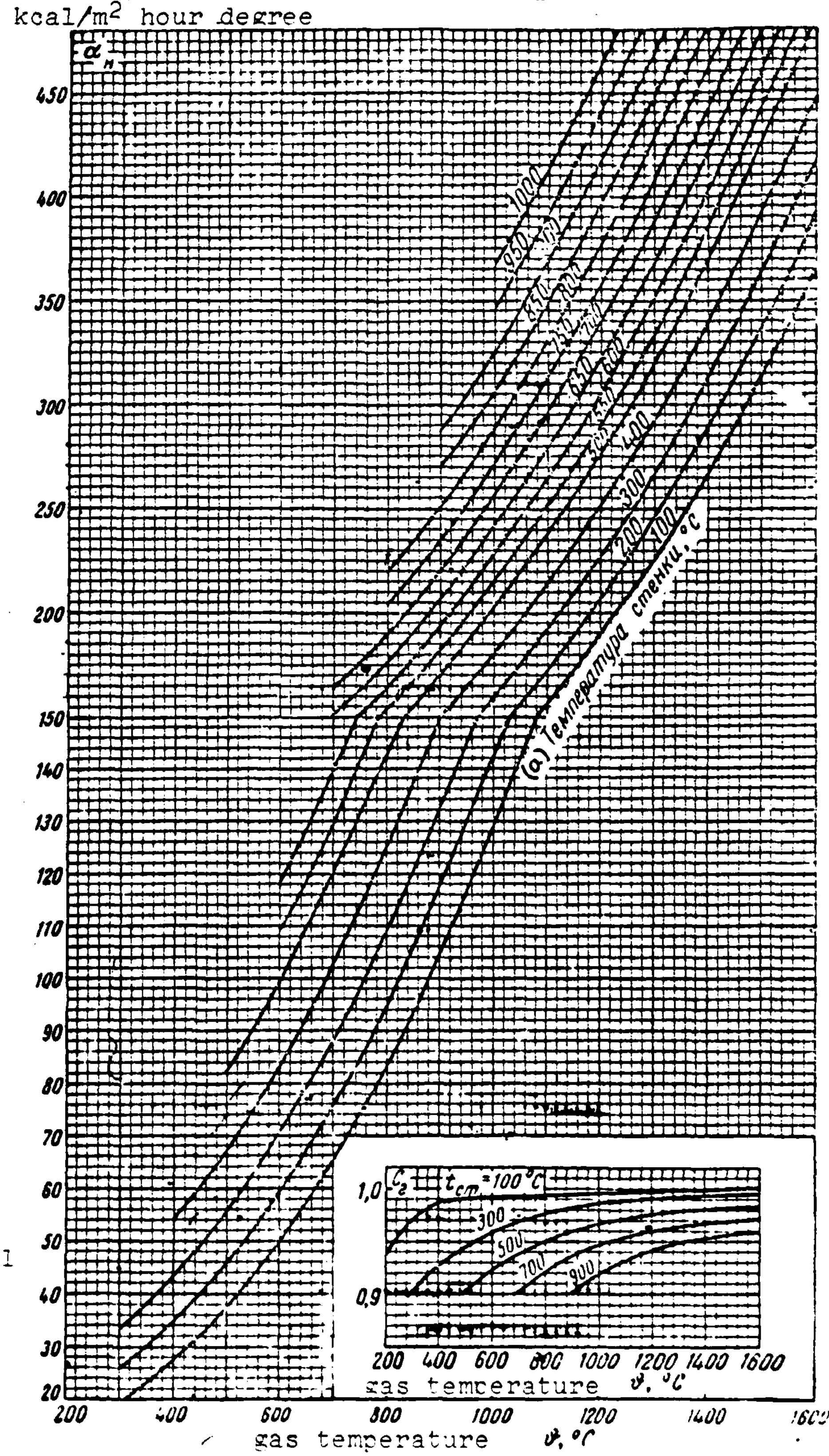
Key: (a) m atm.

| Coefficient of ray attenuation in a space filled with ash dust | Nomogram X |
|---|---|




1 - when burning coal ground in rotary-ball pulverizers;
2 - when burning coal ground in medium- and high-speed pulverizers;
3 - when burning coal and shale in air-swept direct-fired pulverizers;
4 - when burning shredded peat in air-swept direct-fired pulverizer stokers.

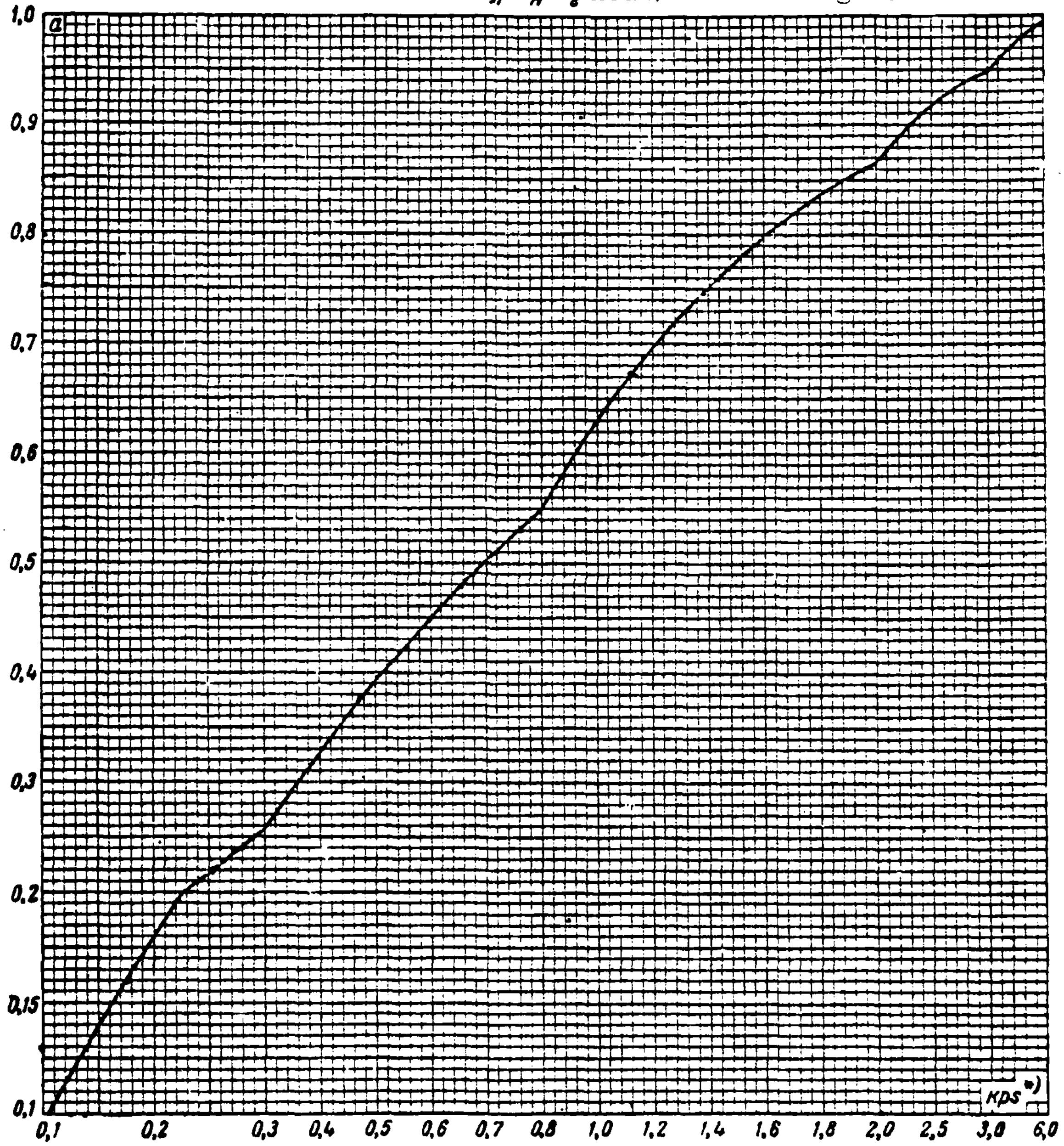
| Coefficient of heat output by radiation | Nomogram XI (page 1) |
|---|---|




Key: (a) wall temperature

| Coefficient of heat output by radiation | Nomogram XI (page 2) |
|---|---|

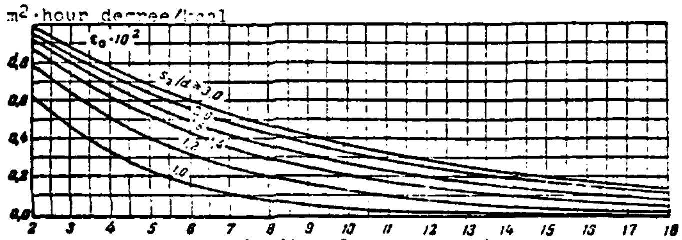
For dusty flow $\alpha_{л}=\alpha_{н}a$ kcal/m$^2$ hour·degree
For clean flow $\alpha_{л}=\alpha_{н}ac_{г}$ kcal/m$^2$ hour·degree



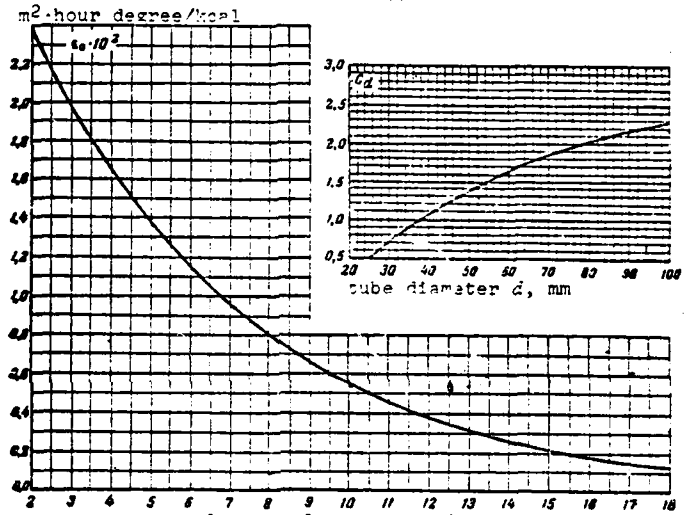

*) For boilers operating without supercharging it is assumed p= 1 atm.

| Dirtiness factor and utilization factor | Nomogram XII (page 1) |
|---|---|

1. Dirtiness factor of plain-tube clusters when burning solid fuels (except wood). $\varepsilon = c_d c_{фр} \varepsilon_0 + \Delta\varepsilon$ $m^2$ hour degree/kcal
Initial dirtiness factor is
$\varepsilon_0$ $m^2$ hour degree/kcal for staggered clusters




$\varepsilon_0$ $m^2$ hour degree/kcal for unstaggered clusters




| Allowing for $\Delta\varepsilon$ | | Allowing for $c_{фр}$ | |
|---|---|---|---|
| Economizer first stages and single-stage economizers* with $\vartheta \leq 400°C$ ............... | 0 | | |
| Economizer second stages and single-stage economizers with $\vartheta > 400°C$, boiler clusters and transition zones of once-through boilers* ........................ | 0.002 | Coal and shale .. | 1.0 |
| | | Peat .... | 0.7 |

* When burning anthracite dust the value of $\Delta\varepsilon$ for coil heating surfaces located behind the main superheater increases to 0.002.

| Dirtiness factor and utilization factor | Nomogram XII (page 2) |
|---|---|

| | | | |
|---|---|---|---|
| Unwound boiler clusters of low-power boilers ........................................ | 0 | | |
| Steam superheaters ........................ | 0.002 | | |

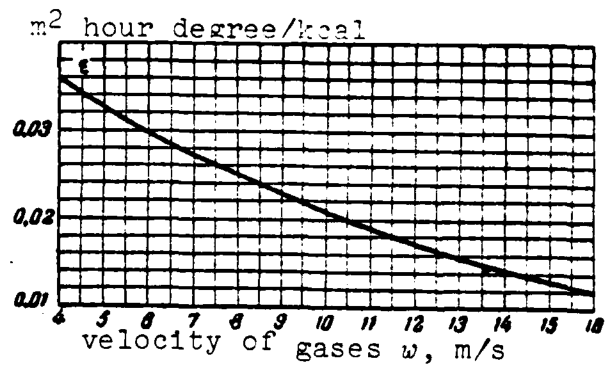
2. Dirtying factors ε when burning liquid, gaseous and wood fuel

| Fuel | Dirtiness factor ε, $m^2$ hr deg/kcal | | | |
|---|---|---|---|---|
| | Boiler clusters | Steam super-heaters | Plain-tube eco-nomizers | Cast iron econ-omizers |
| Fuel oil ...................... | 0.015 | 0.015 | 0.020 | 0.025 |
| Natural gas .................. | 0.005 | 0.005 | 0.005 | 0.010 |
| Wood fuel .................... | 0.010 | 0.008 | 0.012 | 0.020 |
| Blast furnace gas and coke gas | 0.002 | 0.003 | 0.002 | 0.004 |

Data applies to flue gas velocities of not over 15 m/s.

When burning a mixture of fuels the dirtiness factor of the more dirtying fuel is used.

3. Dirtiness factor ε $m^2$ hour degree/kcal for tube clusters with transverse ribs when burning solid fuel.

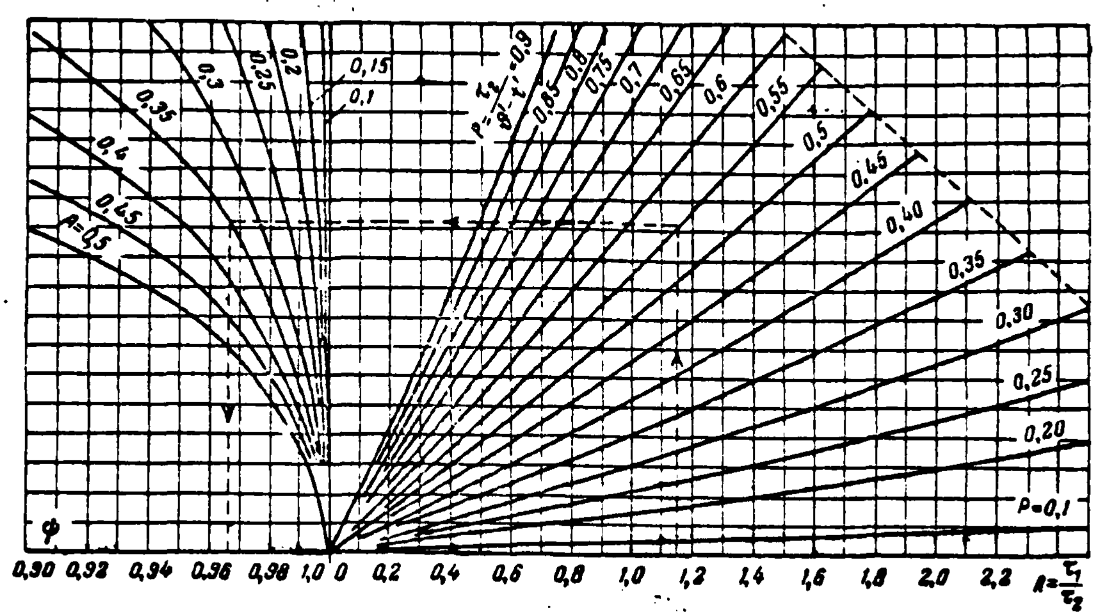



4. Utilization factor

| (a) № п/п | Fuel | (b) Воздухоподогреватели | | | (f) Плавниковые экономайзеры |
|---|---|---|---|---|---|
| | | (c) трубчатые | (d) пластинчатые | (e) чугунные ребристые | |
| 1 | Все топлива, кроме указанных в пп. 2 и 3 . (g) ............ | 0,75 | 0,85 | 0,8 | 0,8 |
| 2 | Мазут (h) ............................ | 0,65 | 0,75 | 0,7 | 0,7 |
| 3 | Природный газ и древесное топливо (i) .............. | 0,70 | 0,80 | 0,7 | 0,7 |

Key: (a) paragraph no.; (b) air preheater; (c) tube-type; (d) plate-type; (e) cast iron rib-type; (f) finned economizer; (g) all fuels except those in paragraphs 2 and 3; (h) fuel oil; (i) natural gas and firewood.

| Thermal head with series-combined current | Nomogram XIII |
|---|---|




$$A = \frac{\text{heating surface of section with direct flow}}{\text{total heating surface}}$$

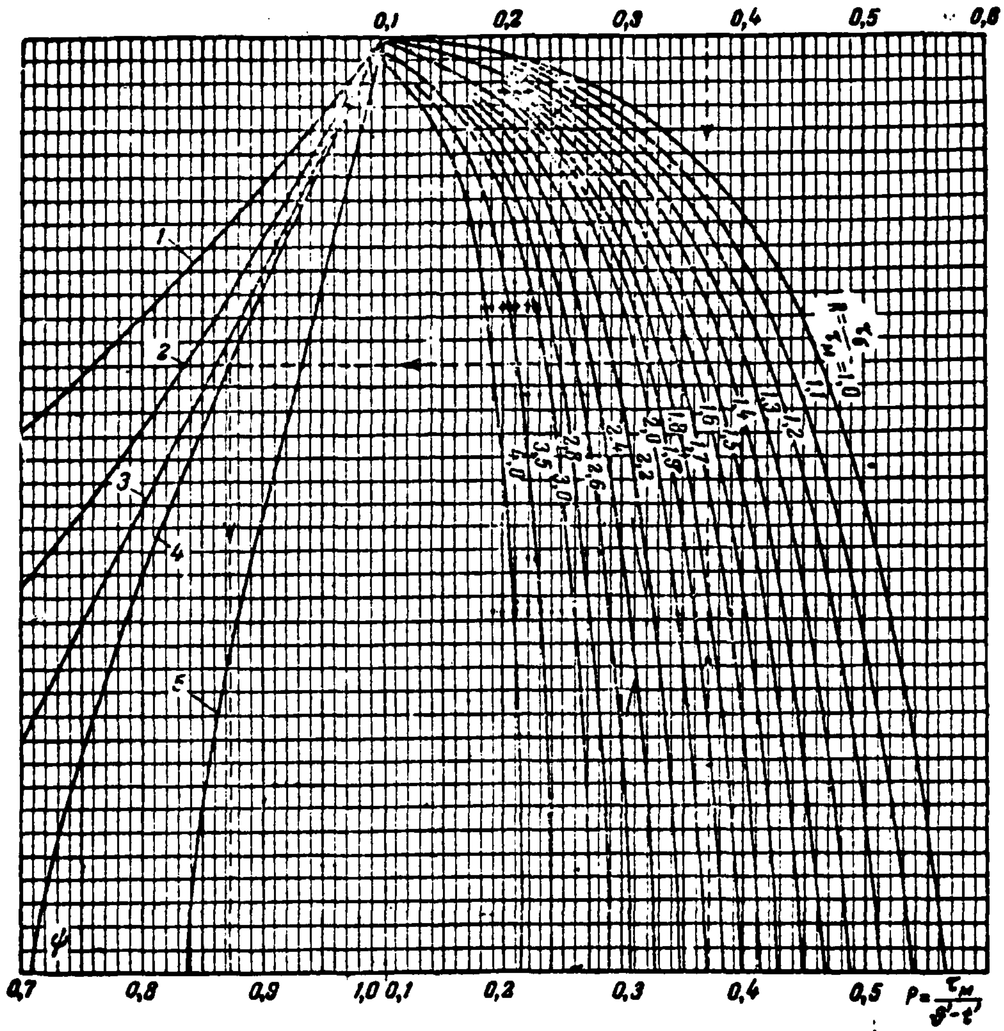
$\Delta t = \phi \cdot \Delta t_{npm}$ °C.

Notes:

1. The nomogram is inapplicable for systems with series-combined current which differ from those shown in RN 7-07.

2. Do not extrapolate the nomogram. If when using it for a specific case it is necessary in some area to go beyond the limits of the lines represented, the calculation of $\Delta t$ should be done part by part.

| Thermal head with parallel combined current | Nomogram XIV |
|---|---|




Curve 1 - both passes of a multipass medium are direct-flow.

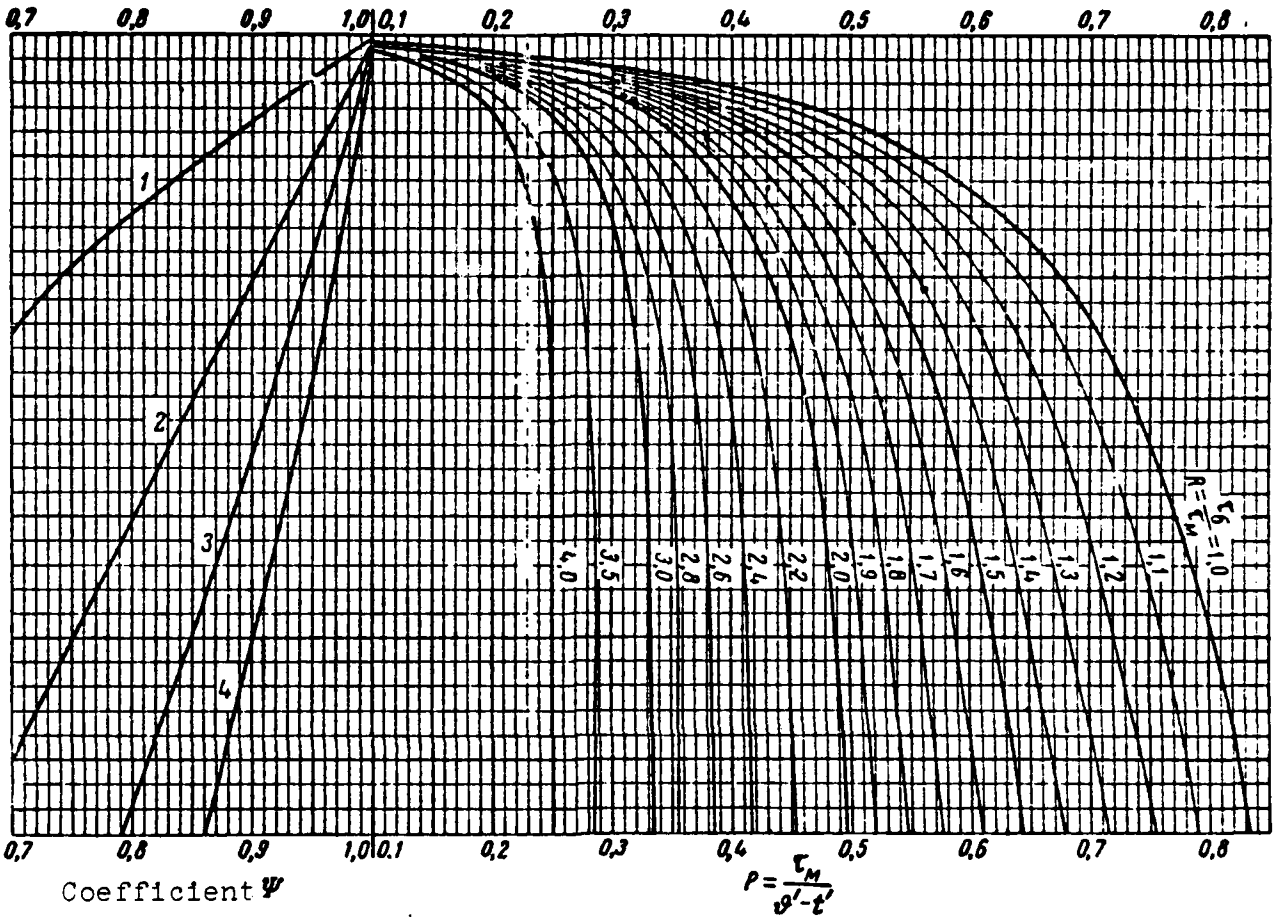
Curve 2 - three passes of a multipass medium: two are direct- and one is counter-flow.

Curve 3 - two passes of a multipass medium: one is counter- and one is direct-flow.

Curve 4 - three passes of a multipass medium: two are counter- and one is direct-flow.

Curve 5 - both passes of a multipass medium are counter-flow.

| Thermal head with cross current | Nomogram XV |
| --- | --- |




Curve 1 - single-pass crossing

Curve 2 - two-pass crossing

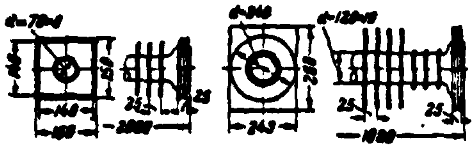
Curve 3 - three-pass crossing

Curve 4 - four-pass crossing

| Coefficient of heat transfer of cast iron ribbed VTI and TsKKB water economizers* | Nomogram XVI |
|---|---|

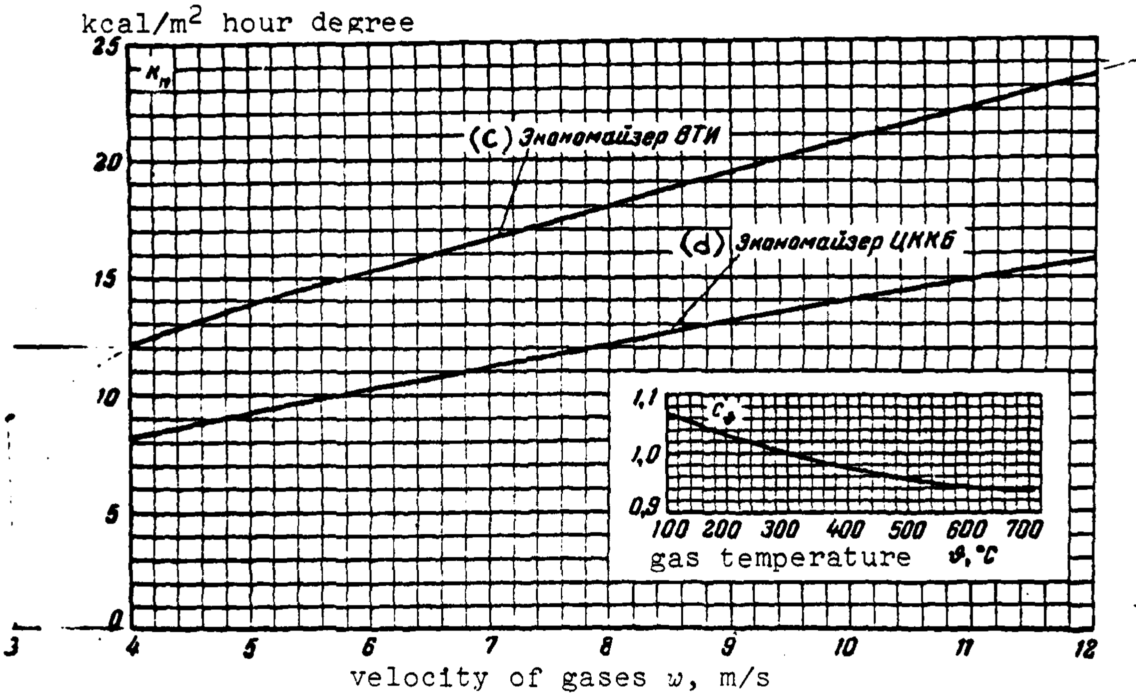
* VTI - All Union Institute of Heat Engineering im. F. E. Derzhinskiy.
TsKKB - Central Boiler Design Office

VTI economizer   TsKKB economizer




| Характеристики одной трубы (a) | Размерность (b) | Экономайзер ВТИ (c) | | | | Экономайзер ЦККБ (d) |
|---|---|---|---|---|---|---|
| Длина (e) | мм | 1 500 | 2 000 | 2 500 | 3 000 | 1 990 |
| Поверхность нагрева с газовой стороны (f) | $м^2$ | 2,18 | 2,95 | 3,72 | 4,49 | 5,50 |
| Живое сечение для прохода газов (g) | " | 0,088 | 0,120 | 0,152 | 0,184 | 0,21 |

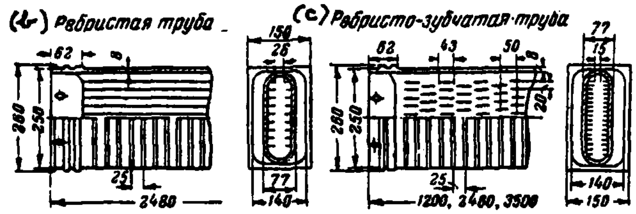
$k = k_н \cdot C_\vartheta$ kcal/m² hour degree



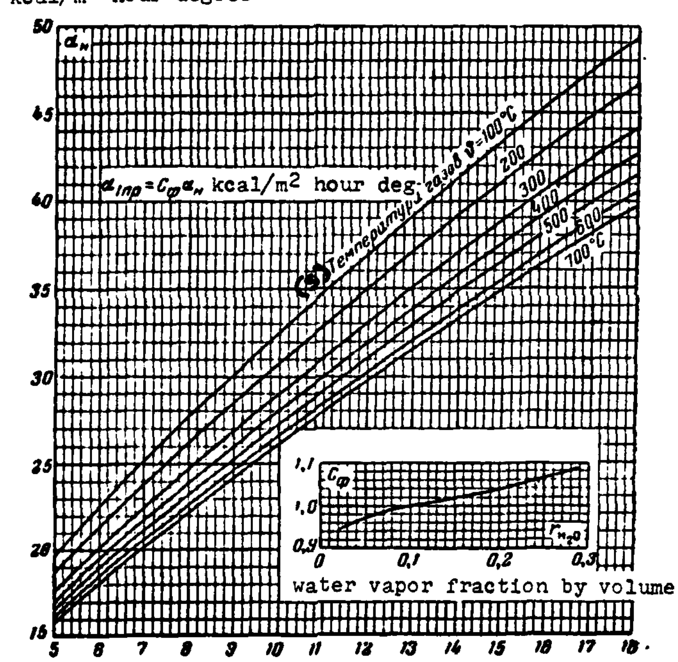

Note: When burning fuel oil the coefficient of heat transfer of cast iron ribbed economizers is decreased by 25%.

Key: (a) Characteristics of one tube; (b) unit of measure; (c) VTI economizer; (d) TsKKB economizer; (e) Length; (f) heating surface on the gas side; (g) cross section for passage of gases.

| Derived coefficients of heat output on the gas side of cast iron ribbed and serrated-rib air preheater | Nomogram XVII |
|---|---|




| Value name | (a) Размерность | (b) Ребристая труба | (c) Ребристо-зубчатые трубы | | |
|---|---|---|---|---|---|
| (d) Длина трубы полная | мм (m) | 2 480 | 1 200 | 2 480 | 3 500 |
| (e) Длина оребренной части трубы | " | 2 275 | 1 000 | 2 275 | 3 300 |
| (f) Поверхность нагрева с газовой стороны (l) на 1 трубу | м² (n) | 4.11 | 1.81 | 4.11 | 5.78 |
| (g) Поверхность нагрева с воздушной стороны (l) на 1 трубу | " | 2.57 | 1.12 | 2.46 | 3.56 |
| (h) Живое сечение для газов (l) на 1 трубу | " | 0.139 | 0,064 | 0,138 | 0,202 |
| (i) Живое сечение для воздуха (l) на 1 трубу | " | 0,0118 | 0,011 | 0,011 | 0,011 |
| (j) Вес трубы | кг (p) | | 73 | 152 | 240 |
| (k) Эквивалентный диаметр с воздушной стороны | м (r) | 0.0426 | 0,0342 | 0,0342 | 0,0342 |

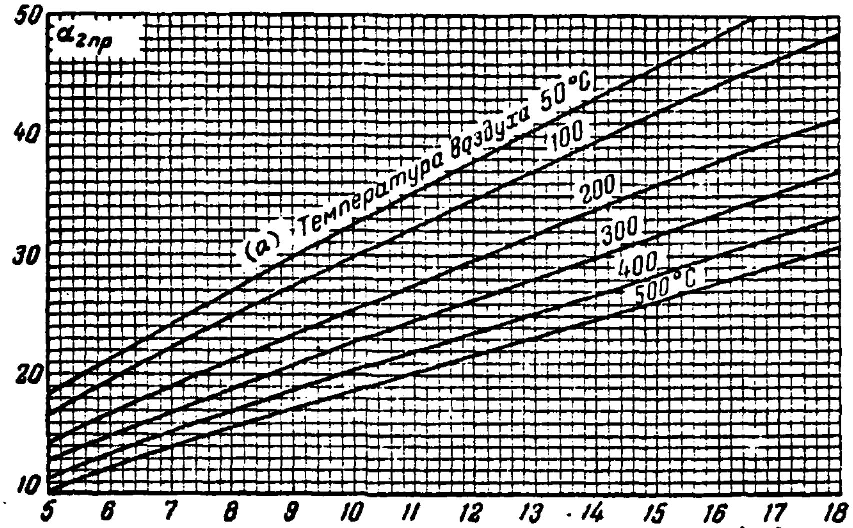



Key: (a) unit of measure: (b) ribbed tube; (c) serrated-rib tube: (d) overall length of tube; (e) length of ribbed part of tube; (f) heating surface on gas side; (g) heating surface on air side; (h) cross section for gas; (i) cross section for air; (j) weight of tube; (k) equivalent diameter on air side; (l) for one tube; (m) mm; (n) m²; (p) kg; (r) m; (s) temperature of gases.

| Derived coefficients of heat output on the air side of cast iron ribbed and serrated-rib air preheaters | Nomogram XVIII |
|---|---|

a) ribbed air preheater

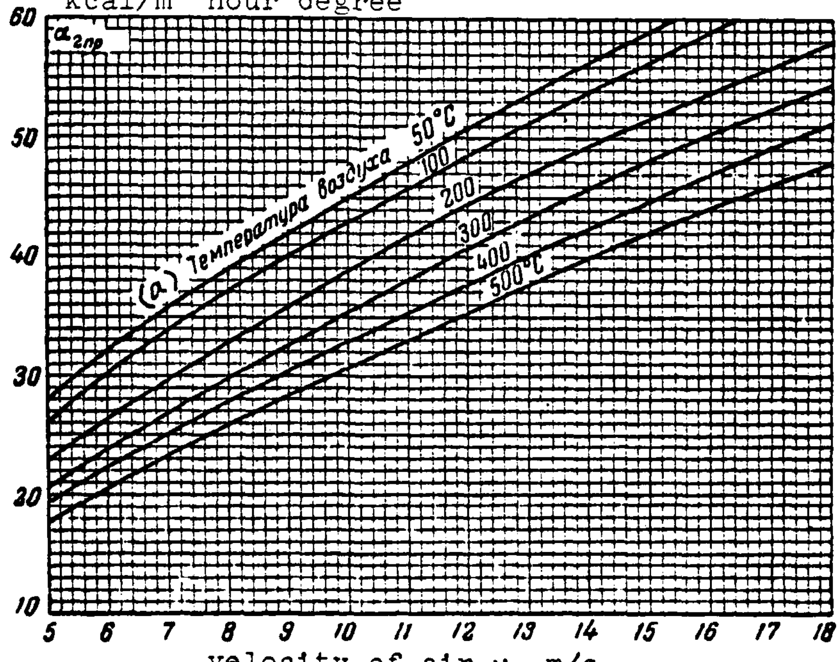
kcal/m$^2$ hour degree




velocity of air $w$, m/s

b) Serrated-rib air preheater

kcal/m$^2$ hour degree




velocity of air $w$, m/s

Key: (a) air temperature

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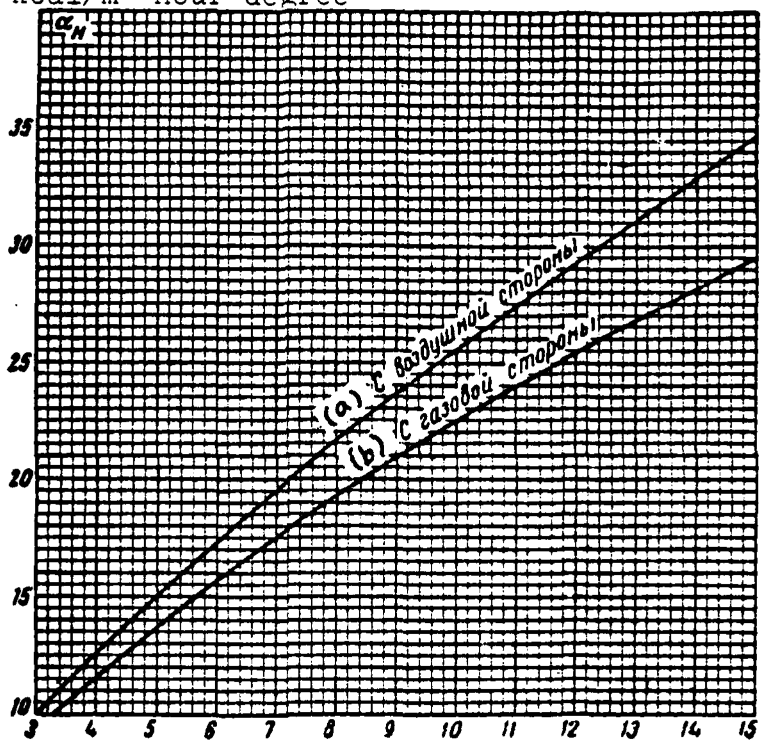
| Derived coefficients of heat output of a cast-iron ribbed plate-type air preheater of Kusinskiy Zavod | Nomogram XIX |
|---|---|

Plate properties

Heating surface on gas side $H_1 = 4{,}8$ м².
Heating surface on air side $H_2 = 2{,}82$ м².
Cross section on gas side $F_1 = 0{,}0485$ м²
Cross section on air side $f_2 = 0{,}0275$ м².

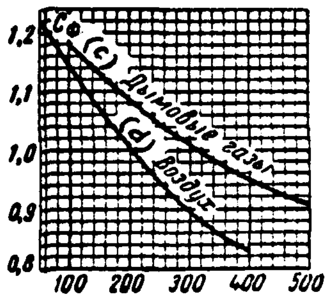
$k = \xi \frac{\alpha_{1пр} \cdot \alpha_{2пр}}{1{,}7\alpha_{1пр} + \alpha_{2пр}}$ kcal/m$^2$ hour degree

kcal/m$^2$ hour degree




velocity of gases (air) $w$, m/s

$\alpha_{пр} = C_\Phi \alpha_H$ kcal/m$^2$ hour degree




temperature, °C

Key: (a) on air side: (b) on gas side: (c) flue gases: (d) air.

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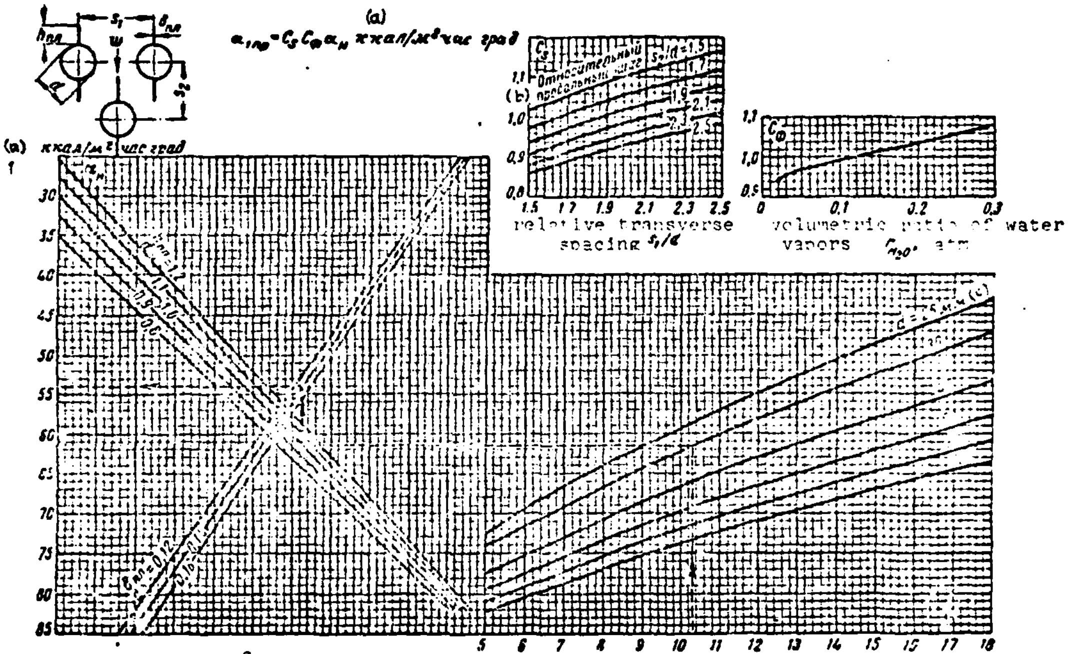
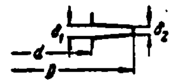
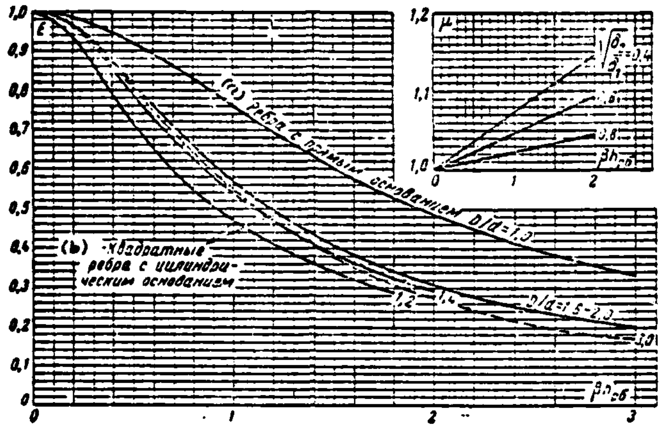
| Coefficient of heat output of staggered clusters of finned tubes | Nomogram XX |
|---|---|

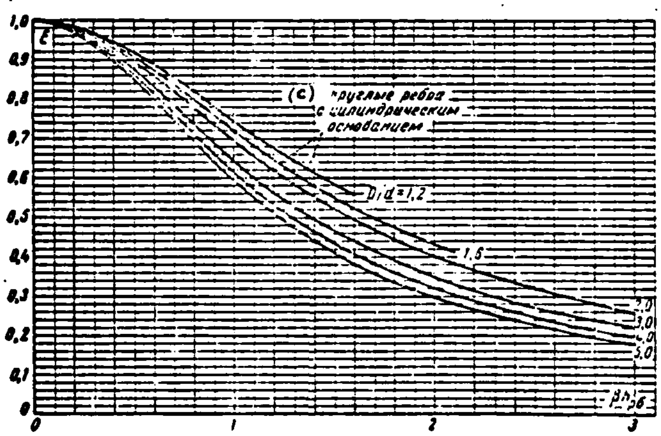



Key: (a) kcal/m² hour degree; (b) relative linear spacing; (c) mm

| Coefficient of rib efficiency | Nomogram XXI |
|---|---|

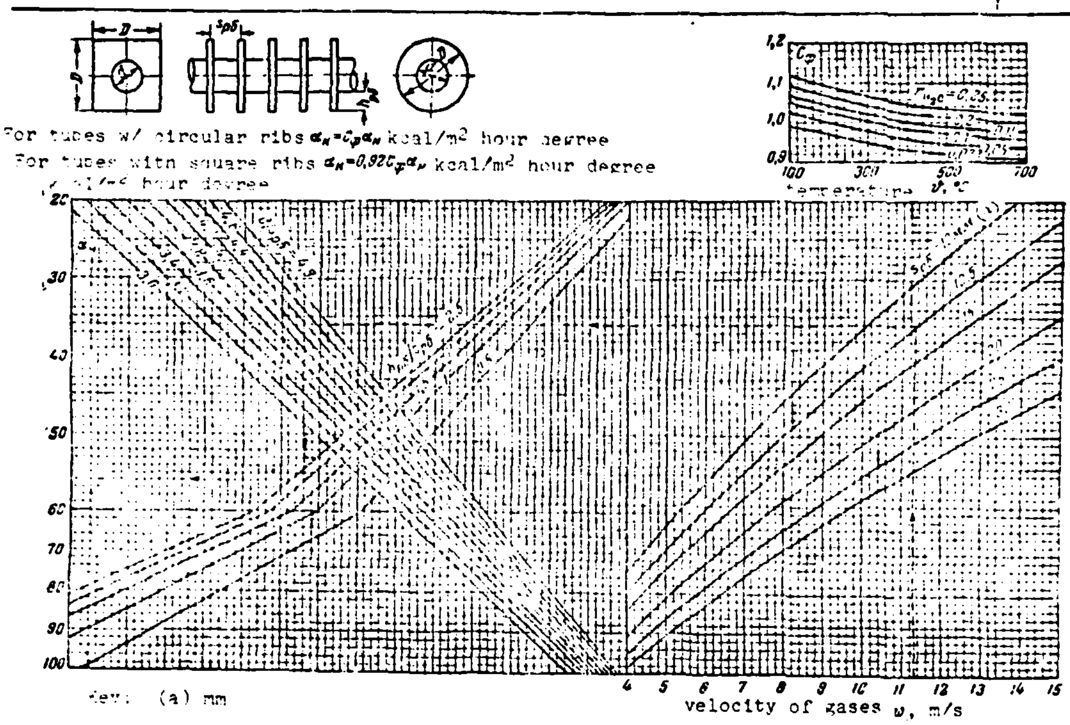




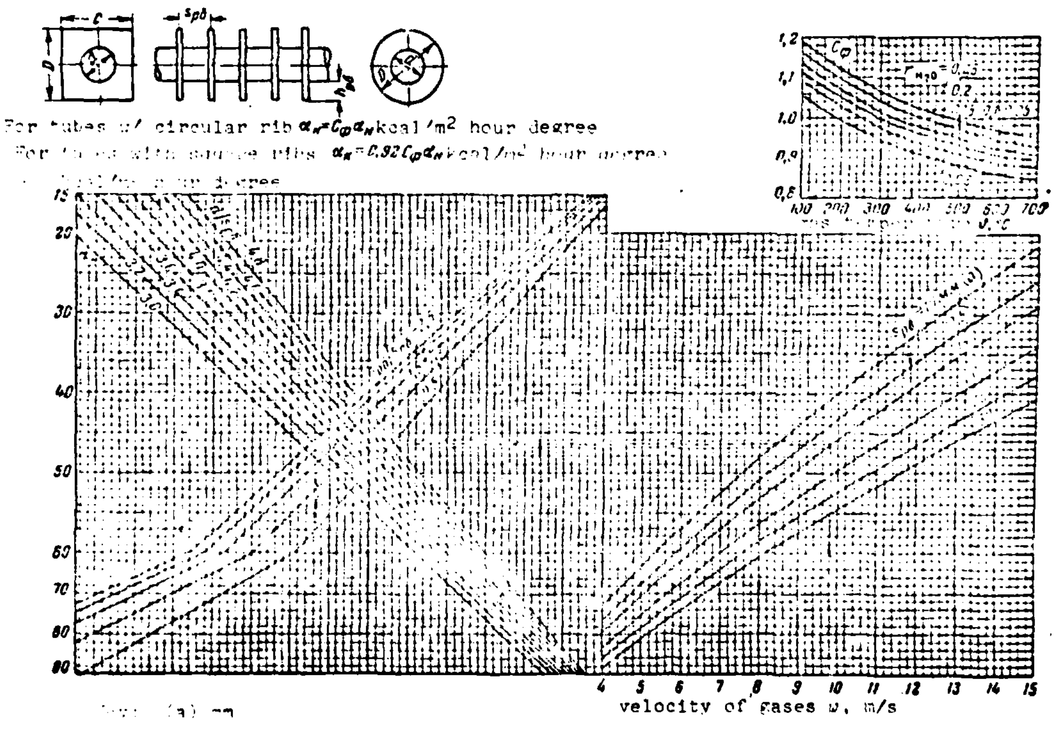




Key: (a) ribs with straight base; (b) square ribs with cylindrical base; (c) circular ribs with cylindrical base.

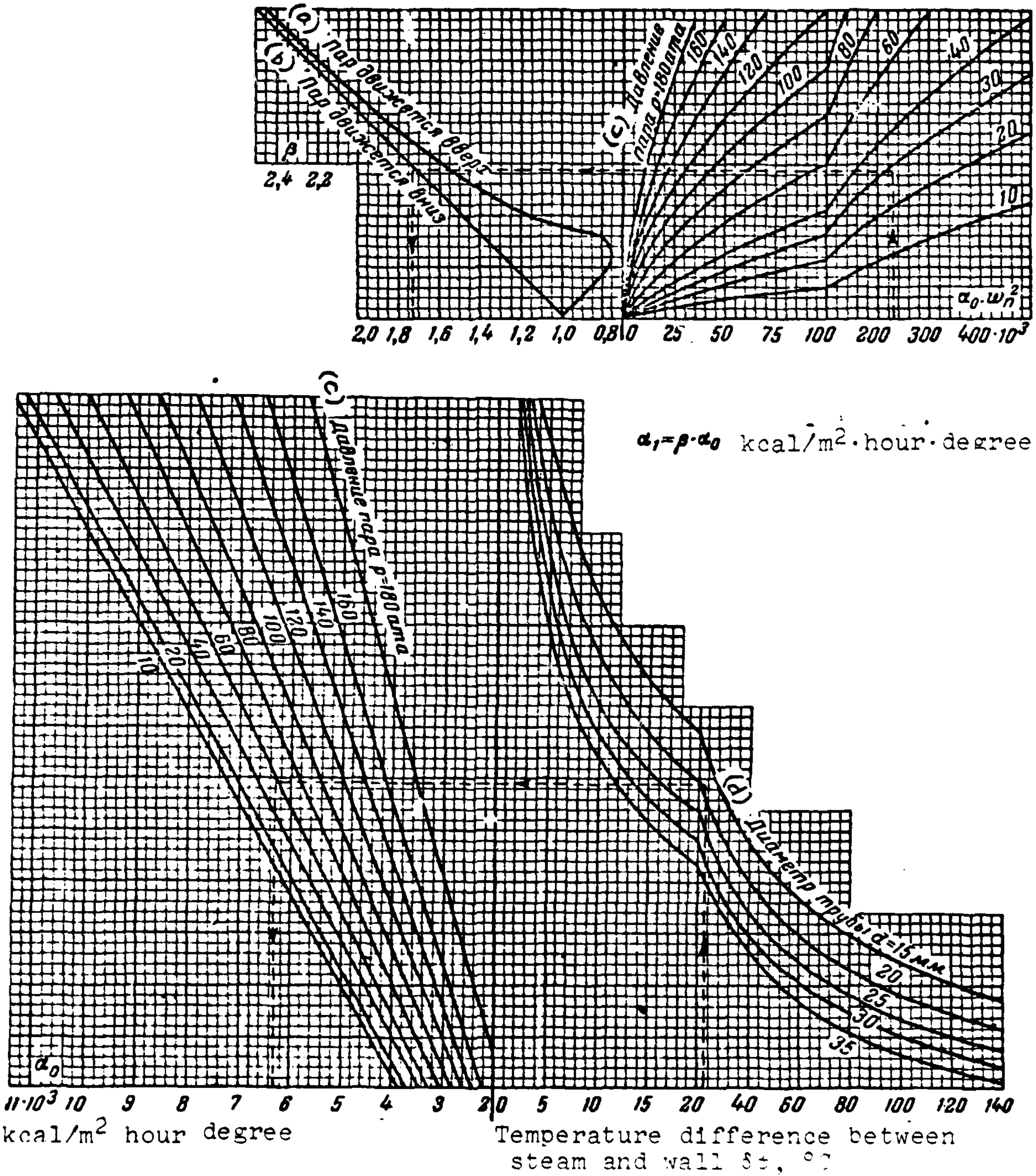
Coefficient of heat output of unstaggered clusters of tubes with transverse ribs | Nomogram XXII




Coefficient of heat output of staggered clusters of tubes with transverse ribs | Nomogram XXIII



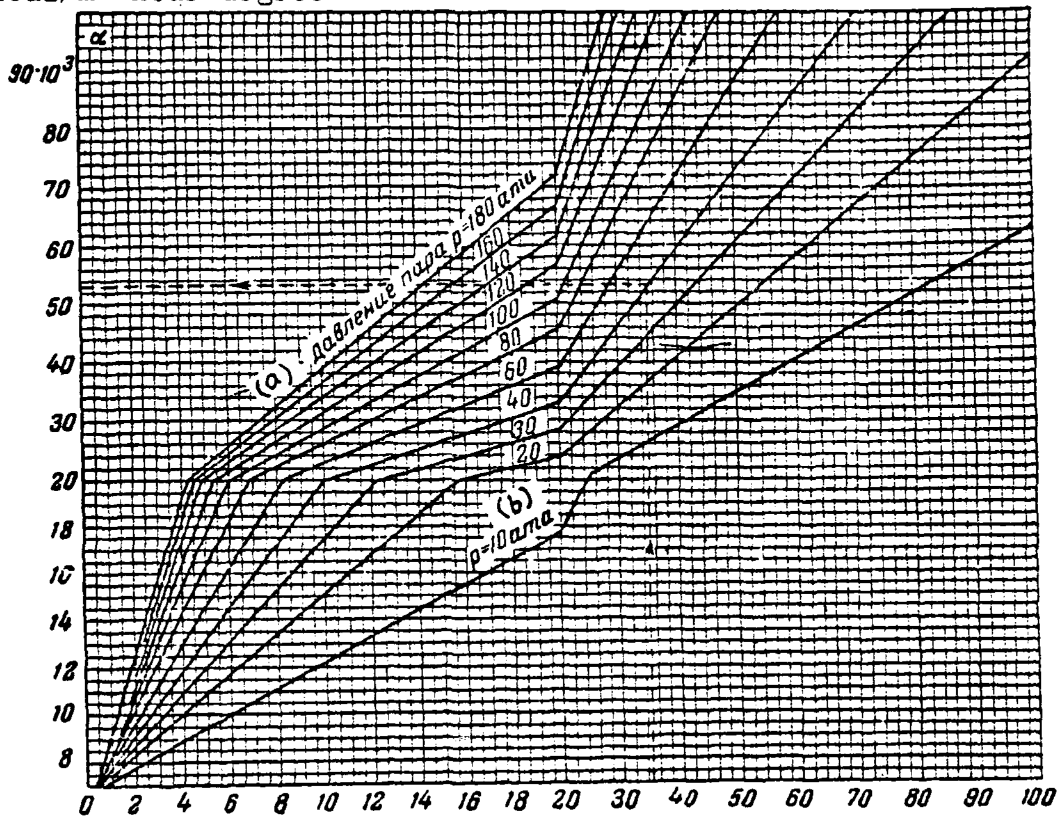
| Coefficient of heat output with steam condensation in a cluster of horizontal tubes | Nomogram XXIV |
|---|---|




Key: (a) steam moves upward; (b) steam moves downward; (c) steam pressure p, atm.; (d) tube diameter d, mm.

| Coefficient of heat output with steam condensation moving along a vertical tube | Nomogram XXV |
|---|---|

kcal/m² hour degree




velocity of steam $w_п$, m/s

Key: (a) steam pressure p, atm.; (b) atm.

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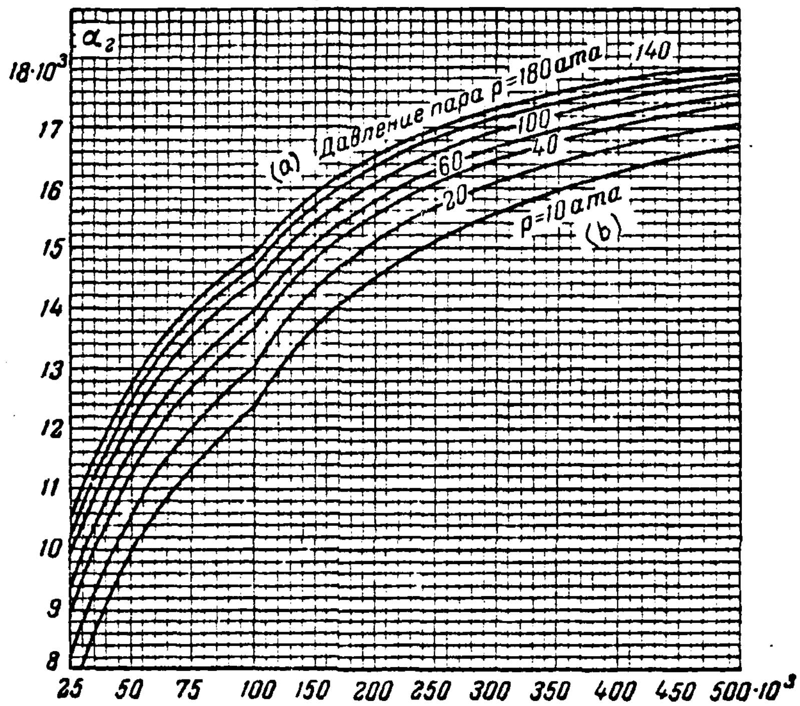
| Coefficient of heat output with longitudinal flow for boilirg water | Nomogram XXVI |
|---|---|

kcal/m2 hour degree




Heat input $q$, kcal/m$^2$ hour

Key: (a) steam pressure $p$, atm.; (b) atm.